GEOLOGY OF THE GOVERNEUR QUADRANGLE

BY

H. P. CUSHING

AND

D. H. NEWLAND

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GEOLOGY OF THE GOUVERNEUR QUADRANGLE

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INTRODUCTION

This report has been prepared, by instruction of the State Geologist, to meet a quite insistent local demand. There is a considerable production of limestone, feldspar, talc, pyrites and zinc blende within the quadrangle limits; a number of people are keenly interested in the mineral development, are actively engaged in prospecting, and greatly desire a more accurate and serviceable areal map of the district than has heretofore been available. Both Mr Newland and myself are under obligation to several of these gentlemen for courtesies of many kinds, freely extended on many occasions.

The Gouverneur district was the starting point from which Professor C. H. Smyth prosecuted his important work on the Precambrian geology of the western Adirondacks, work which did much to establish the fundamental basis of our present knowledge. By all rights of service and of priority in the region he should have prepared this report, and the writer undertook the task with the greatest reluctance and only when it became evident that the work could not be delayed, and that Professor Smyth was not in a position to do it at this time. The areal mapping which is the basis of this report does little more than to reproduce Smyth's earlier results upon a more accurate map of larger scale. The indebtedness of the present work to his can not be made too emphatic.

Doctor Buddington was engaged in mapping the Lake Bonaparte quadrangle, next south of Gouverneur, during the 1916 season. We studied our joint boundary together, to our mutual advantage and pleasure.
Newland, who reports upon the economic geology of the quadrangle, has made trips into the region for many years past, and the knowledge of the areal geology which he had thus acquired has been most helpful. We have also been together at some points in the field, particularly in the Edwards-Talcville vicinity. Except for the economic geology report, Cushing is responsible for the presentation of the geology.

LOCATION AND CHARACTER

The territory comprised in the Gouverneur quadrangle extends from latitude 44° 15' to 44° 30', and from west longitude 75° 15' to 75° 30', containing a trifle over 220 square miles. It lies entirely in St Lawrence county but is near its southwestern margin. Large portions of the towns of Dekalb, Gouverneur, Hermon and Fowler lie within it, and smaller parts of Edwards, Macomb and Depeyster. The Canton, Ogdensburg and Brier Hill quadrangles, which lie respectively northeast, north and northwest from it, have already been mapped, and the mapping of the Lake Bonaparte quadrangle, directly south, has been completed. The Hammond quadrangle, just west, intervenes between Gouverneur and Alexandria Bay. Topographic maps of the quadrangles on the east and southeast are not yet available.

The district lies entirely in a single topographic and geologic province. With the exception of many small and scattered patches of Potsdam sandstone, its surface rocks are exclusively of Precambrian age, though they lie near both the westerly and the northerly limits of these rocks within the State. To the north they disappear beneath the Paleozoic rocks of the St Lawrence trough about midway of the Ogdensburg quadrangle. Beyond doubt these Paleozoic rocks formerly extended over the entire Gouverneur quadrangle, and have been removed from its surface by erosion, except for the few scattered remnants of Potsdam sandstone. To the west the Precambrian rocks continue across the Hammond and Alexandria Bay quadrangles, but with constantly narrowed area, until they ultimately reach the river and cross into Canada. This narrow neck of these rocks which connects the Canadian Precambrian area with that of New York is known as the Frontenac axis. It separates the Paleozoics of the St Lawrence trough from those of the Black river valley, and narrows westward because of their convergence in that direction. To the east the Precambrian rocks extend unbroken across the Adirondack region, almost or quite to the shore of Lake Champlain.
Topographically also the Gouverneur quadrangle belongs with the Adirondack region, or at least with the western Adirondack region, notwithstanding its low altitude. There is a rather steady diminution in hilltop altitudes in passing west from the middle of the Adirondacks, and there is no topographic break whatever between the Adirondack quadrangles and those of the Frontenac axis region. The country consists in each case of alternating ridges and valleys; the only difference lies in the amount of elevation of the ridges above the valley bottoms, and this amount steadily increases as the general altitude increases eastward.

The Gouverneur quadrangle, together with its western neighbor, the Hammond quadrangle, is noteworthy in comparison with all other Precambrian quadrangles of northern New York for the great areal extent occupied by Grenville rocks, and more particularly by Grenville limestone. Hence a much larger part of the territory is well adapted to agricultural pursuits than is usual.

GENERAL TOPOGRAPHY

Both from the topographic and the geologic standpoints, the Gouverneur quadrangle belongs with the Adirondack highland province, notwithstanding the fact that its general low altitude would seem to naturally exclude it from any highland province.

The lowest altitudes on the quadrangle are found on the water courses along its northern and northwestern margin. The Oswegatchie river at De Kalb, where it passes on to the Ogdensburg sheet, is about 310 feet above sea level. The level of Mud lake is 316 feet. The 300-foot contour line crosses Beaver creek just south of the north line of the quadrangle, and this is the only appearance of this particular contour line within the quadrangle. In this same vicinity the highest elevations are found along the ridge of Huckleberry mountain, where three or four knobs slightly exceed 500 feet altitude, so that the extreme topographic range here is about 225 feet.

In the southeastern portion of the quadrangle, a few knobs attain elevations of 900 feet, in one case 920 feet, while the level of the Oswegatchie at Edwards is 650 feet, so that the extreme topographic range here is 270 feet. The extreme range for the entire quadrangle is 625 feet.

The hilltops thus slowly increase in altitude from northwest to southeast, with a total gain of 400 feet; while the valley floors also gain in altitude, although somewhat less rapidly, so that the relief is slightly more at the east.
The same decline in elevation in a westerly direction continues across the Hammond quadrangle, although somewhat more slowly, the difference in the hilltop altitude across this quadrangle being 300 feet or less, as contrasted with the 400 feet of the Gouverneur quadrangle.

It is quite certain that the hill summits steadily increase in altitude, and it is highly probable that the rate of increase becomes more rapid in that direction, just as it is more rapid on Gouverneur than on Hammond. It is also true that the general relief becomes greater in passing east.

**Peneplains**

The Adirondack district has an inherent tendency to be elevated, and to move upward rather than downward during times of oscillation of level in the crust of the earth. Such a region is spoken of as positive, to distinguish it from districts of the negative type, whose tendency is to sink rather than to rise. At certain times in the past the margins of the highland have become sufficiently depressed so as to pass beneath sea level and become overspread by marine deposits. The Gouverneur district belongs to this marginal portion, but the central area of the highland seems never to have been depressed sufficiently to carry it below sea level, or rather never since very early in Precambrian time; since then it has had a continuous existence as a land area. From time to time it has been reuplifted, and its surface has experienced much erosion. Between the periodic uplifts long ages of comparative stability have intervened. Slow erosion of the surface by the streams and the rains has been continually going on. During stable intervals the streams cut their valleys to base level, and can cut them no deeper; but after this stage is reached the slow process of valley-widening still continues, and if sufficiently prolonged tends to wear down the entire surface to comparative evenness with comparatively low altitude. Such an erosion plain is called a peneplain. If a peneplained district experiences renewed uplift the streams commence to cut their beds down to the new base level thus created, and the whole erosion process is again set in motion.

The Adirondack district has been thoroughly peneplained certainly twice during its long history and quite likely more than twice. These two times stand out prominently because of the thoroughness of the peneplanation. The earlier of the two was completed in Precambrian time. Then its margins sagged beneath the sea, and upon these depressed margins the early Paleozoic deposits of northern
New York were laid down, beginning with the Potsdam sandstone. These deposits covered and preserved this old erosion surface; but in their turn they have been and are being worn away, and as they disappear portions of the old peneplain surface emerge from beneath and form the present surface, furnishing an exhibit of its characters. Its comparative evenness is surprising when the great variation in resistance to erosion of the rocks composing it is considered.

The entire surface of the Gouverneur quadrangle corresponds to this old peneplain. The scattered patches of Potsdam sandstone are the last vanishing remnants of the former cover of Paleozoic rocks, and they show that the removal of this cover by erosion is the most recent geologic episode of the district, and that the surface of the Precambrian rocks underneath is substantially that which they formerly covered. The altitude of the district is so low, and the time which has elapsed since the cover was removed is so short, that modern erosion has affected the old peneplain surface only in trifling degree. The characters which it possessed when first covered, far back in the remote past, are those which are exhibited on the present surface. It was and is a surface of moderate relief. The more resistant rocks form the elevations, the weaker ones the valleys; the granites and the Grenville quartzites and certain hard gneisses stand above the valleys which are floored by Grenville limestones and certain weak schists. The extreme of relief was and is between 200 and 300 feet. The sky line of the ridge tops is exceedingly even. This Precambrian peneplain was developed over a great area in Canada and New York, and today forms the surface of that portion of the Precambrian which lies near the Paleozoic border.

A much later peneplain, of probable late Mesozoic date, was also developed in the region, and again it was merely the local development of a peneplain which had wide extent in eastern North America. Prior to its development, deformation of the Adirondack region had upwarped the older peneplain into the form of a gentle dome, and at the same time downwarped the margins into shallow troughs, in which early Paleozoic sandstones, limestones and shales had been deposited. The Mesozoic peneplanation truncated the domed summit of the older peneplain; but on the margins of the region the two surfaces intersect and the older passes beneath the younger. The Paleozoic rocks rest upon the surface of the older peneplain, and the younger cuts across them (figure 1). An attempt to illustrate the manner in which, by erosional stripping back of the Paleozoic cover,
portions of the old peneplain surface are exposed to view and form the present surface of the marginal portions of the Adirondacks is seen in figure 2.

Fig. 1. Domed surface of Precambrian peneplain, b b b, with marginal Paleozoic deposits, both truncated by late Mesozoic peneplain, a a a. Vertical scale much exaggerated.

Fig. 2. Diagram in illustration of the manner of reappearance of the old Precambrian peneplain at the present surface; a b = late Mesozoic peneplain; c d = tipped surface of old peneplain, in part covered by Paleozoic rocks; from c to e, however, the Paleozoics have been recently removed by erosion, reexposing the old peneplain surface; modern erosion has cut valleys in both peneplain surfaces but the ridge summits are remnants of these surfaces.

Since the development of the Mesozoic peneplain, the Adirondack highland has experienced further uplifts. These have been most pronounced in the eastern portion of the region, along what is today the chief axis of elevation of the Adirondacks. In the western Adirondacks the elevation has been progressively less, and the concordant hill top elevations of that district are remnants of the Mesozoic peneplain. Still farther west, in the comparatively low district of the Gouverneur quadrangle, the elevation has been but slight. As uplift took place valleys began to be trenched in the surface of the peneplain, and the present ruggedness of the western Adirondacks is due to this valley carving. In the Gouverneur region the whole territory has been worn down below the level of the Mesozoic peneplain, but the surface rocks were Paleozoics, and the modern Precambrian surface is due to their slow stripping away. Since this Paleozoic cover disappeared, the general low altitude has prevented any great depth of valley cutting, resulting in the comparatively small difference in elevation between valley and upland which the quadrangle exhibits.

Pleistocene Deposits

In common with the general region of which it is a part, glacial deposits are scant over the surface of the quadrangle. There are no prominent moraines, no thick accumulations of till; rock knobs
abound everywhere, and the valleys are not deeply filled. The larger part of the quadrangle was for a time submerged beneath the bodies of standing water which occupied the general region while the glacial ice was disappearing and after its disappearance. The level of the earlier of these bodies, Lake Iroquois, on the quadrangle today, stands at about 800 feet, so that all of the area except the higher knobs of the wilderness district in Edwards and Hermon, in the southeast corner of the quadrangle, have been washed by its waves. The succeeding marine waters have in like manner wave washed all territory below 475 to 480 feet, and this comprises most of the northwest half of the quadrangle.

Owing to the topography, the shore lines of these bodies of water across the quadrangle were of the highest irregularity, long narrow bays were separated from one another by equally long, narrow promontories, which tailed out into frequent islands. The course of the 800-foot contour across the map will give a good idea of the Iroquois shore, and that of the 480-foot contour an even better one of the marine shore line. The chief effect of these waters was to wash the rock ridges fairly clean of loose rock material which was deposited as valley filling in the depressions between the ridges. The material so washed into the depressions consisted largely of fine clays, and the filling was comparatively even, so that the valley surfaces are now relatively flat, and the rock knobs and ridges rise sharply out of these flats, as though their lower slopes were drowned by the valley filling, as in fact they are.

When Lake Iroquois existed, the larger streams which emptied into it built large sand deltas at their mouths; and the delta of the west branch of the Oswegatchie, formed at that time, is one of the prominent topographic features of the quadrangle. This delta extends from Harrisville (7 miles to the south of the sheet margin, on the Lake Bonaparte quadrangle) nearly to the mouth of the Branch at Hyatt. It is comparatively narrow since the valley is margined on each side by fairly high land, but it will average some 1½ miles in breadth. It is about 10 miles long and its northern 3 miles lie within the Gouverneur quadrangle. Its higher portion has an altitude of 800 feet, which gradually descends to 700 feet at its northern margin. The present course of the river is along the west margin of the delta. The material is a pure, medium-grained sand. Its surface is so much moved about by the winds that vegetation obtains a foothold only here and there, and east and south of Fullerville are wide expanses of this loose, drifting sand. The whole con-
stitutes the comparatively small delta of a small stream. The larger delta of the main river is in Pitcairn township. The great sand plain between Carthage and Philadelphia is the huge delta built by the Black river in the same water body. The 800-foot level of the upper surface at Fullerville indicates for us the approximate level of the lake at the time the delta was forming.

The shore currents in these bodies of standing water often built bars and spits of sand and gravel, tailing out from the ends of the rock promontories of the shore line. An excellent example is found at Cole, where a sand and gravel spit, over a mile long, runs out to the southwest from the low ridge of hard gneiss just to the north.

There is one hill of moderate size upon the quadrangle, at Kents Corners in the northeastern portion, which appears to be a true drumlin, and entirely of glacial origin. It is of oval shape, with the longer axis north-south, nearly a mile long and a half mile wide, its crest nearly 100 feet higher than the land to the north, and 50 feet higher than that to the south. It stands on granite territory and rock outcrops abound on all sides. But it is composed of bouldery, sandy clay, the boulders very abundant but mostly small, with many large ones lying upon its surface. This hill is noteworthy as being the only one of the type within the quadrangle, and as occurring in a district in which the drift is elsewhere very thin and scanty.

A thin band of moraine, with very little surface relief, stretches across the northern part of the quadrangle, following the limestone belt which runs south of west through East De Kalb. The accumulation is thick enough to hide most of the rock surface along this belt, although occasional rock knobs peep through. The upper surface is flat, and also stony, boulders being plentiful and large. Undoubtedly the surface was smoothed by wave action, and the same action was no doubt responsible for the concentration of boulders at the surface, owing to the washing away of the finer materials in which they were originally embedded.

DRAINAGE

Except for a comparatively narrow strip along the middle-eastern and northeastern portion of the quadrangle the drainage is entirely into the Oswegatchie river and through this into the St Lawrence river at Ogdensburg. The Carter creek-Tanner creek drainage, with its sources in Trout lake, Huckleberry lake and Moon pond, runs off to the northeast and empties into the Grasse river between Pyrites and Canton, on the Canton quadrangle, finally to reach the St Lawrence below the Long Sault rapids.
The Oswegatchie is the most southerly of the four rivers of good size which drain out to the northwest from the Adirondacks and are tributary to the St Lawrence, the other three being the Grasse, Raquette and St Regis. They all rise in the heart of the woods and flow down the northwesterly sloping peneplain. Their present courses are not those which they had preglacially, and are a patchwork of portions of preglacial valleys and other portions which are wholly postglacial and the work of the modern streams. All have a comparatively rapid drop, and exhibit frequent rapids and waterfalls. All flow northwest, across the general trend of the rock structures, which is northeast-southwest. All pursue very erratic courses, with frequent changes in direction. As they near the St Lawrence all swing from northwest to northeast courses, although this change is not so prominent and is more complicated in the case of the Oswegatchie than in that of the other three streams. On the other hand, the Oswegatchie shows a much greater disposition to double back upon itself than the others exhibit.

The minor drainage conforms to the type exhibited everywhere in the New York Precambrian area, what is called the trellised type. The streams flow either parallel to the grain of the country, in valleys eaten out along the belts of weak rock, or else at right angles to this, cross-cutting the rock belts. Such streams as Beaver creek, Carter creek and Tanner creek are predominantly of the first type, flowing long distances along the trend of a single, narrow belt of weak rock; while the lower part of Boland creek, as it flows past Richville into the Oswegatchie, is typical of the other class. Most of the modern drainage, however, is a patchwork of the two types: a stream follows one valley for a distance, then transects a ridge in a narrow valley or gorge into the next adjacent valley, follows that for a space and then shifts across to yet another (plate 1). This is in part due to modifications in their courses produced as a result of glacial action in the region; in other part it is due to the rock structures themselves, since the rocks are folded. The ridges run for a distance and then pitch down below drainage and a weak rock belt wraps around the ridge end. The granite ridges affect the drainage similarly, as in the case of the branch of Indian creek which wraps around the north end of Moss ridge.

The course of the Oswegatchie across the Gouverneur and Hammond quadrangles furnishes an excellent illustration of all these features. From the river at Gouverneur to the river at Peabody bridge is 3 miles straight across country, and only a trifle more by
the wagon road. It is 25 miles by the river between the two points. From Gouverneur the river keeps on in a course slightly south of west to Oxbow, more than half way across the Hammond sheet, where it sweeps round the south end of a series of ridges into a northeasterly course, which closely parallels its previous course for a distance of 4 miles, in two parallel, weak rock valleys. At Wegatchie it is only about 250 yards across the neck of land between the two parallel portions of the river, although it is 5 miles by water from one place to the other. At Little Bow, near the margin of the Gouverneur quadrangle, the river makes a double curve back upon itself, of broad S-shape, occupying short portions of two parallel valleys and swinging round the ends of two ridges, then passing into the valley which, with little variation, it follows across the Gouverneur quadrangle to its north edge and beyond. Other Adirondack streams show a similar doubling back upon their courses, as the Indian river at Evans Mills on the Theresa quadrangle, but no other has this feature in such prominence as the Oswegatchie river.

In its course across the quadrangle the Oswegatchie river shows falls or rapids at Talcville, Hyatt, Emeryville, Hailesboro and Gouverneur, with narrow, rock-cut gorges below the falls. The west branch has a fall at Fullerville. In all these places the stream is in a wholly modern channel. The reaches, in between the falls, may be all developed along portions of the valleys of small, preglacial streams, and in part are certainly so developed, but the river course as a whole is an entirely modern affair. As a contrast to this, the lower portion of the river, from Little Bow to De Kalb, is a long reach in a preglacial valley of moderate size, with no falls whatever. Not a single contour line crosses the stream in this part of its course and the difference in water level between the two points is not over 15 feet; while in the somewhat shorter distance between Edwards and Natural Dam the river drops 260 feet, and 100 feet of that drop is between Hailesboro and Gouverneur.

Lakes

There are a dozen lakes and ponds on the quadrangle, and perhaps an equal number of basins, where shallow lakes formerly existed, but where filling has been completed and the basin is entirely occupied by swamp. Of the still existing ponds, Mud pond, near Sylvia lake in Fowler, is simply a small body of open water enduring in the center of a basin which has otherwise passed over into swamp. Sylvia lake, Trout lake and Mud lake are the largest bodies of water which are wholly or partly within the quadrangle.
Plate 1

Tanner creek emerging from a transecting valley in porphyritic granite into a broad Grenville valley; locality just north of Rock Hollow School.
All these ponds, large and small, filled and unfilled, seem to belong to a single type. They all occupy weak rock belts and were portions of preglacial valleys; all are blocked at one or both ends by a small thickness of glacial deposit, so that their outlets are in modern courses; and the outlets are too small to have any erosive power. Cedar lake, just north of Edwards near the eastern border of the quadrangle, is the only one which may perhaps occupy a real rock basin, but it connects directly with swampy territory, both to the south and to the east, and would apparently have a clear path to the Oswegatchie, between Edwards and Talcville, except for slight glacial filling in between.

All the villages in the region obtain their water supply from the Oswegatchie, along which they lie. The river water, however, is by no means as unpolluted as could be desired, and these lakes might be utilized as a source of a much purer supply.

CULTURE

Roughly speaking the surface of the Gouverneur quadrangle is about 50 per cent cleared and utilized for agricultural purposes, while the other half consists of wild land. The belts of unmixed limestone are completely cleared, the impure limestones and schists largely so, and some of the broader granite areas, such as the one in Gouverneur and the Maple ridge belt in De Kalb, make excellent farming territory. In these latter there are frequent bare knobs of granite which stand above the general level, but except for these the surface is comparatively even and, with a sufficiently thick morainic covering that is not very stony, furnishes an excellent soil. The dairy industry is the chief one, and hay and oats are the principal crops.

In contrast, the relatively elevated territory whose surface rocks are amphibolites, garnet-gneisses and granites, is chiefly wilderness. The timber was cut away long ago; fires followed, and now thickets of bushes, briers and small trees cover the land. The most extensive areas of the sort are the garnet-gneiss territory in Edwards, in the southeastern part of the quadrangle, and the granite, garnet gneiss, amphibolite tangle in Hermon, Edwards and Fowler, lying chiefly north of the river, but cut through by it between Hyatt and Hailesboro. There are many smaller patches of similar country elsewhere, but these are closely surrounded by better land and are partially cleared and somewhat used for pasture. The densely wooded swamps in the filled lake basins also belong in the wilderness category.
The exposed rocks of the Gouverneur quadrangle are chiefly of Precambrian age. The only exceptions to this are the frequent but small patches of Potsdam sandstone, found here and there, resting on the unevenly worn surface of the crystalline rocks, and the glacial deposits which form the immediate surface over much of the district. About fifty separate patches of Potsdam sandstone are shown on the map, and there are many others which are too tiny to be mapped upon this scale. They represent the residuum of what was formerly a great sheet of sandstone which overspread the entire Precambrian surface, with the possible exception of a few of the higher knobs.

The Precambrian rocks of the quadrangle comprise both sedimentary and igneous rocks, as is invariably the case in northern New York. But the igneous rocks greatly exceed the sediments in quantity in most of the quadrangles, and the Gouverneur region is quite exceptional in the large area of sediments shown. All these sediments are classed in one ancient and thick group of rocks, the Grenville series. No trace of any other sedimentary series of Precambrian age has ever been discovered in northern New York.

The Grenville rocks are also the oldest rocks exposed. Being a group of sediments they must have been deposited on something, but no certain trace of this old floor of deposit has ever been discovered in New York. While it is always possible that some such find may be made, it seems today most probable that this old floor was entirely engulfed in the great floods of molten igneous rock which attacked it from beneath.

The igneous rocks of the region are all of Precambrian age and all younger than the Grenville, as they all cut the sediments intrusively, notwithstanding the fact that the sediments rest on them. They are believed by the writer to belong to three separate groups of widely different age: an early group consisting chiefly of gneissoid amphibolites and granites, the former older than the latter; a considerably later group comprising anorthosite, syenite, granite and gabbro; and a still later group consisting chiefly of diabase. All three groups are believed to be represented in the Gouverneur quadrangle.

The Grenville rocks are found to be quite sharply and closely folded, in a series of isoclinal folds, which often show a sharp pitch. The granite-gneisses of the early group occur in bosses or bathyliths of oval shape. The porphyritic granites of the later group appear
here as sills, a rather exceptional mode of occurrence for these intrusives in northern New York. The Grenville rocks seem to have been already metamorphosed and folded to about their present extent, before the intrusion of these sills took place; and the sills themselves seem to be up-shoots from a large mass of syenite and porphyritic granite below ground, whose upper surface has not yet been reached by erosion.

**GRENVILLE SERIES**

Crystalline limestone and garnet-gneiss are the most important members of the Grenville series within the Gouverneur quadrangle. The great belt of limestone which extends across the map from southwest to northeast is the local exhibit of what is the longest and thickest belt of Grenville limestone in northern New York, as was long ago pointed out by Smyth. It by no means consists exclusively of pure limestone; there is a great thickness of impure, quartzose limestone, a rock described by Martin as “quartz-mesh” limestone as it occurs on the Canton quadrangle.¹

As pointed out by him this rock varies through imperceptible gradations into limestone, on the one hand, and into quartzite, on the other. There are also bands of hard gneisses of various sorts interbedded with the limestone. But even after these deductions there remains an enormous amount of exceedingly pure, massive limestone.

The garnet-gneisses are a common member of the Grenville series everywhere in northern New York. In many cases they are inter-banded with other gneisses with the formation of a complex whose members are too thin to be mapped separately. Nowhere else in the region have we seen this rock in such purity and with such great areal extent as it possesses on the Gouverneur quadrangle. It is not only readily mapped separately but it covers many square miles of territory.

The bands of hard gneiss interbedded with the limestones are chiefly made up of hard, flinty, fine-grained rocks, of reddish, grayish or greenish hue, which invariably carry tourmaline as a constituent, sometimes black, at others brown or white. Such rocks are quite a feature of this immediate district, but are rare elsewhere, so far as our experience goes.

Many thin bands of pyrite (rusty) gneiss, of mica-gneiss (both coarse and fine grained), and of quartzite occur within the quad-

¹ N. Y. State Mus. Bul. 185, p. 22–23.
rangle, but mostly too thin and too interbanded to justify separate mapping. In comparison with other parts of the region, the lack of thick formations of these rocks, especially of the quartzites, is noteworthy.

**Structure**

The strongly-folded condition of the rocks makes it difficult to arrive at any precise estimate of the stratigraphy or the thickness of the Grenville series here. The garnet-gneiss is the oldest member shown within the quadrangle, and appears in outcrop along the axes of anticlines; it is directly overlain by the thick limestone member, which is pinched into synclines between the garnet-gneiss belts. By the same token, it would appear that the belts of hard schist within the limestone in the northwestern half of the quadrangle belong just above it stratigraphically and occupy synclinal axes within the folded limestone. In this same portion of the quadrangle the garnet-gneiss fails to reach daylight along the anticlinal axes, suggesting that the folds form part of the western limb of an anticlinorium, or the eastern limb of a synclinorium, so that higher and higher beds appear in passing northwest; and that probably the schists and quartzites of the Alexandria Bay quadrangle belong yet higher in the section than any of the rocks shown on Gouverneur. Between the two lies the Hammond quadrangle, and this has not yet been mapped in detail. In the abundance of Grenville and the relatively small amount of intrusives it much resembles the Gouverneur quadrangle. Its Grenville consists of successive belts of limestone and of schists, and its careful mapping should greatly aid in the elucidation of the general structure.

In the Alexandria Bay section evidence was presented suggesting that the thick limestone of the eastern portion of the Theresa and Alexandria Bay sheets, was folded into a syncline, with a series of schists beneath and another of schist and thick quartzite above it.\(^1\) The schists beneath do not at all suggest the garnet-gneiss which underlies the big limestone of Gouverneur. The garnet-gneiss is an injection-gneiss, and it is perhaps possible that the schists of Alexandria Bay would become converted into garnet-gneiss by means of "lit-par-lit" granite injection. But the Alexandria rocks are of the "green schist" variety, are much cut by granite, and yet bear no resemblance to the garnet-gneiss. They seem to have been originally rocks of higher lime content than the garnet-gneisses could have pos-

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\(^1\) N. Y. State Mus. Bul. 145, p. 109–11.
sibly been and appear to us to represent an entirely different member of the Grenville. If so, the limestone which overlies them can not be the same formation as the great limestone of the Gouverneur quadrangle, but must be a higher member of the series, and an unknown thickness of schist lies between. Whether the hard schists which overlie the limestone on Gouverneur represent the basal portion of the schist formation which underlies the limestone on the Alexandria sheet, or whether other members intervene on the Hammond sheet, is a question, the answer to which must await the detailed mapping of the latter. Lithologically they are quite similar, calcareous pyroxene gneisses being a prominent constituent in each case.

In so far as the Gouverneur quadrangle alone is concerned, attempts to estimate the thickness of Grenville shown are comparatively futile. The folds are complex; a limestone syncline or a garnet-gneiss anticline can not be treated as simple folds in efforts to measure thickness. On the contrary, the field facts demonstrate that the limbs of the large folds are themselves contorted into minor flexures. If the interpretation of the stratigraphy of the region which has just been set forth comes anywhere near the truth, the Grenville section of the district is something as follows:

<table>
<thead>
<tr>
<th>Section</th>
<th>Thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Quartzite and schist</td>
<td>3000'</td>
</tr>
<tr>
<td>4 Limestone</td>
<td>4000'</td>
</tr>
<tr>
<td>3 Hard schists, largely green schists</td>
<td>4000'</td>
</tr>
<tr>
<td>2 Limestone</td>
<td>5000'</td>
</tr>
<tr>
<td>1 Garnet-gneisses</td>
<td>4000'</td>
</tr>
</tbody>
</table>

Because of the complex folding these thicknesses are mere estimates. No. 3 is the most uncertain member, and study of the Hammond sheet may greatly expand it, and may show an additional member or members between Nos. 2 and 4. But all thicknesses are subject to much correction, that of the limestones especially so because of their massive character and of their plasticity under compression.

If, because of the general northeast strike and northwest dip, the structure be regarded as that of an unbroken monocline, then this reasonably unbroken section, extending across the full width of three quadrangles, would have a prodigious, an unbelievable thickness.
Grenville limestone

Two belts of crystalline limestone extend across the Gouverneur sheet, one of which, the great belt already referred to, occupies the entire northwest half of the quadrangle, except for certain infolded bands of schist of no great thickness, and for various intrusive masses of granite and amphibolite; the other the band which crosses the southeast corner of the sheet, from Sylvia lake to Edwards. In each case the limestone rests on garnet-gneiss, suggesting that the stratigraphy is the same and that we are dealing with two synclinal troughs carrying the same limestone member. The Edwards band is much narrower than the other and consists chiefly of impure, quartzose limestone. Much impure limestone also occurs within the other belt, especially in its basal portion. But nothing has been noted in it which can be definitely correlated with the talcose member of the Edwards belt; and the sphalerite deposits are also confined to it, as far as is known. These differences might be thought to suggest that we are dealing with two distinct limestone members; but the similar stratigraphy, together with the known folded structure, leads to the belief that the same limestone is concerned; that the Edwards band is not so deeply down-folded as the other, because of which only the basal portion of the member is present there, instead of the full thickness as is the case in the other belt; and that the talc and zinc deposits of the Edwards belt were formed because of local conditions which failed to obtain in the great belt.

The limestone is of two general types, the comparatively pure and the very impure, although there are, of course, many intermediate types. Each type shows much variation.

The larger part of the pure limestone is of white color and of medium-coarse grain; but there is much and often rapid variation in the latter respect, the rock running from very fine to very coarse grain. Tiny flakes of brown mica (phlogopite) and of graphite and occasional small crystals of pyrite are invariably present but in small quantity, much of the rock running from 95 per cent to 99 per cent calcite. A faint bluish tinge is perhaps a more common color than the dead white, although there is much of each sort. There is also quite an amount of rock of prominent bluish gray color, although there is much less of it than of the light-colored rock; and sometimes the two colors are interbanded, the bands sometimes narrow, at others wide (plate 2). But by no means is all the banded limestone of the district of this type; more commonly it is due to alternating bands of pure and of very impure limestone.
Color-banded Gouverneur limestone, by the state road near Pine Hill School, Macomb township, Hammond quadrangle; a better exhibition of such limestone than was anywhere seen on the Gouverneur quadrangle. Strike northeast and dip northwest. View looks northeast.
Gouverneur limestone in Corrigan & McKinney pit north of Gouverneur looking west along north wall of pit to the northwest corner. Solid, massive, white, pure limestone.
Neither is there any large quantity of banded limestone of any type within the quadrangle limits. The great bulk of the rock is of very light color and so massive that the bedding is made out with great difficulty if at all. The rock is cut by more or less frequent joints, often quite irregularly, and at the surface these are frequently widened by solution. In plate 3 is shown the exposure of limestone at the Corrigan and McKinney pit, near the railway 2 miles north of Gouverneur. On the left of the view the limestone is exceedingly solid, massive and pure, while midway is a zone with abundant jointing.

No great amount of dolomite has been observed within the quadrangle limits, outside of the Edwards-Sylvia lake belt. We have seen nothing to correspond with the brown-colored dolomite formation which Miller and Knight describe underlying limestone in the Grenville, in several districts in Ontario. In fact we have seen very little brown limestone of any sort in northern New York, whether magesian or not. The great mass of our pure limestone is white, rather than blue, unlike that in Ontario, although much of ours is faintly bluish. There is, however, some dolomite present on the Gouverneur quadrangle, but in no great quantity and within the general mass of the rock, rather than at its base. Within the belt of limestone at Rock Island School, 4 miles north of Gouverneur, and thence southwest toward Peabody bridge, is a considerable mass of dolomite. To the eye it presents little to distinguish it from the limestone, as it is a coarsely-crystalline, white marble, and, as such, it is excellently shown in the quarry one-half mile southwest of Rock Island School. But often, as at the school itself, it contains much tremolite, both as single-bladed crystals shot through the rock, and in great, spherically-aggregated masses of crystals. The band has no great width and is bordered by ordinary limestone on both sides.

It is not to be understood that the tremolitic phases are confined to dolomite. Tremolite is quite common in the limestone also, in so many localities that it is not worth while to give a list. Sometimes pyroxenes of light color in long crystals appear. An accessible locality of this sort occurs just out of Gouverneur on the Hailesboro road a short distance south of the cemetery. Here a nose of one of the main quarry ridges of limestone comes to the roadside and has been blasted. The rock is somewhat impure, of bluish color, and contains many stoutish, but nevertheless long prismatic, crystals,

1 Bur. of Mines, Ont. v. 22, pt 2.
up to 3 inches in width and with length about 4 times the breadth, whose crystal form seems to prove the mineral to have been originally pyroxene. It is now completely altered to a nearly black material of uncertain nature.

Tourmaline Locality.

Certain silicified bands, or spots, are also found within the pure limestones. A notable instance, which may serve as a type, is found at the well-known brown tourmaline locality. This is situated on the Reese farm, southwest of Richville and 2 miles from the town on the Richville-Rock Island School road, and is the locality from which museums have been furnished with the excellent specimens of this mineral, usually labeled as from Gouverneur. This is correct if it is understood that the township is meant and not the village. Some ten pits have been opened on the "pay streak" which is spottily developed along a comparatively narrow band in the limestone for a distance of some 300 yards. Great masses of coarsely crystallized lime-magnesium silicates, tremolite and diopside, are developed in the limestone, and tourmaline crystals are thickly sprinkled through these, notably the tremolite, and through the accompanying coarse calcite. Apatite, phlogopite mica, titanite and pyrite are also associated but in comparatively small amount. The band is wholly inclosed in pure limestone, no nearby igneous rock showing. The small knobs of white granite near Richville are 2 miles distant; the granite-gneiss margin lies one-quarter of a mile away to the south. Yet the mineral association at the occurrence is so typically of the sort which would be produced by the attack upon limestone of hot, siliceous solutions given off from some nearby granite mass, solutions containing mineralizers in quantity though lacking iron, that the occurrence is most reasonably explained on the assumption that granite occurs in place not far below ground, and that solutions given off from it worked upward through the limestone, attacking it and giving rise to the silicates.

Impure Limestone

The impure limestones of the district are of two types, those which have arisen from the metamorphism of portions of the limestone that were originally impure, and those made impure by contact action of igneous rocks. The first type is widespread in the quadrangle; the second is local and in but small bulk.
The lower portion of the great limestone of the quadrangle seems originally to have been quite siliceous. It has metamorphosed to a calcite-quartz mixture, ranging all the way from pure limestone to pure quartzite, although the greater part of the rock contains more, usually much more, calcite than quartz. Sometimes the two minerals are quite intimately mixed; but the quartz tends usually to coarseness of crystallization, with the formation of knots and lumps of quartz within the limestone, or to the construction of a coarse, quartzose mesh with calcite-filled interstices. On weathering, the less soluble quartz stands out in relief on the rock surface. At other times the quartz forms thin bands in the limestone which, in mashed portions of the rock, become disrupted into angular fragments which are squeezed apart and separated from one another by movement in the more plastic calcite.

With increase in the amount of quartz, these impure limestones grade toward and pass into thin-bedded quartzites; but there is relatively little of such rock in the quadrangle, although there is much of the quartzose limestone. The belts mapped as impure limestone consist chiefly of this rock. In the Edwards belt, especially around Sylvia lake and thence northeast, is a great thickness of interbanded quartzite and limestone, both thick and thin bands of each in rapid alternation which in many places have not been greatly pressure-disrupted, that seems to represent a metamorphosed member originally made up of rapidly alternating limestone and sandstone beds. The same belt in the vicinity of Fowler shows vastly more disturbance and disruption.

The talc deposits are in this general series, usually in the near vicinity of amphibolite masses. As Smyth showed long ago, the original rock was a tremolite schist, consisting of tremolite with a varying amount of quartz, the tremolite largely altered to talc.1

An unusual variety of impure limestone occurs in this same belt, usually in close association with the zinc deposits. The limestone is full of lumps and masses of green serpentine, of all dimensions and often of quite irregular shape. In a small proportion of these, particularly of the smaller ones, the mass consists entirely of serpentine, but the larger number have a peripheral serpentine band and a central nucleus of gray, impure talc.2 On weathering these nodules whiten and, because they are less soluble than the limestone, project in relief from the weathered surface (plate 4). The inclosing limestone is also of the ophicalcite variety, a dolomite-serpentine

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1 School of Mines, Quarterly, v. 4, p. 333-41.
2 See plate. The serpentine rims of the nodules in the figure are somewhat thinner than the average, and the talc centers correspondingly larger.
aggregate of varying coarseness. Such ophicalcites are quite common in the Grenville of northern New York, and have resulted from the alteration of pyroxene to serpentine in original dolomite-pyroxene limestones, such as are next described. The talc centers of the nodules form a very unusual feature.

Between Gouverneur and Hailesboro the pure limestones show, locally, angular included fragments of hard, black amphibolite, which represent the disrupted fragments of either a narrow bed of amphibolite, originally interbanded with the limestone, or of a narrow dike of the gabbro-amphibolite.

White or green pyroxene and scapolite are two other minerals which are of quite common occurrence in the limestones. Even in the very pure rock, which seems to consist entirely of calcite, close inspection will show one or both of these minerals to be present. Thus in the Gouverneur marble belt, south of the village, where the most active quarrying is done, the white limestone contains white pyroxene in many localities, and the blue bands contain often much green pyroxene in small, roundish crystals, as well as some scapolite. From such rocks as these are found all gradations to impure limestones which contain 50 per cent or over of pyroxene and scapolite, and from such onward into rocks in which the calcite practically disappears, and the abundant calcium of the rock is all in combination with silica. Such rocks, however, are not particularly abundant in the quadrangle, but are of local occurrence only, and in comparatively small amount. They are most common in De Kalb in the extreme northeastern portion of the quadrangle where there is much impure limestone.

Grenville Schists

There are four belts of schist which run across the quadrangle, and two others consisting of schist involved with amphibolite and granite. Four belts of clean schists are found in the northwestern half of the quadrangle, infolded with the limestone and, because of local sharp pitch, pinching out within it. Two of the belts are in the extreme northwest, in the vicinity of the branches of Beaver creek. They pinch out in the limestone to the southwest and are comparatively short. They coalesce into one belt at the north edge of the sheet and pass as such on to the Ogdensburg quadrangle. Four miles to the northeast, on that quadrangle, limestone swings round the end of the belt and cuts it out. These two belts are conveniently described together and will be called belt no 1.
Belt no. 2 comes on the sheet from the Hammond quadrangle 2 miles north of Natural Dam, very narrow at first, and remaining so for 4 miles. Below Rock Island bridge it rapidly expands to a width of well over a mile. For all this distance the Oswegatchie closely follows it. Below the Richville bridge a great boss of gabbro-amphibolite cuts out the western half, but the remainder has a breadth of a full mile. Three miles below Richville it becomes indented with the great limestone which splits it into two unequal arms; and 3 miles farther away both belts pinch out, and limestone swings around their ends.

Belt no. 3 appears in the limestone at the west edge of the village of Gouverneur as a narrow belt, and runs north to the edge of the granite-gneiss which cuts it out. South of the river its presence is uncertain, the country in that direction being low and covered with drift. What seems to be the same belt reappears on the east margin of the granite-gneiss, and runs steadily to Richville depot as a narrow belt. Beyond that it broadens considerably and continues across the quadrangle and on to the Russell quadrangle beyond. At this end it becomes involved with amphibolite to a large extent. The belt is noteworthy in that it contains a very persistent band of quite pyritiferous rusty gneiss along its east margin.

Belt no. 4 runs southwest from the zinc mine near Edwards, passing through Talcville and on to the edge of the stock of amphibolite where, at the west branch of the Oswegatchie, it is cut out. It is in contrast with the other belts in being much more involved with dikes and sheets of amphibolite than they are. At its northern end, where it pinches out in limestones, it consists largely of granite and amphibolite. A mass of very red granite cuts it at Talcville. Elsewhere the schists prevail, but always with intermingling of the intrusives.

There is a varied assemblage of rocks in these schist belts, both in appearance and in composition, although all are referable to comparatively few types. The range is from very siliceous rocks—quartzites—down to those with no free quartz and low silica percentage. The bulk of the formation, in most cases, consists of rather fine-grained, hard, resistant rocks, often almost flinty in appearance and consistency, hence the belts stand somewhat in relief above the adjacent limestone country, and show frequent sharp, and often rugged, knobs.

Quartzite occurs in all the belts, and particularly so in no. 1. It occurs in both thick and thin beds, in part finely granular and in part coarsely crystalline. But the rock is always interbedded with
the schists so that there is nothing within the quadrangle at all comparable to the thick quartzite formation of the Alexandria Bay and Grindstone quadrangles of the Thousand Island region. There is a particularly large amount of quartzite in the broad schist belt to the west of Osborn lake, to the north of the amphibolite stock. This is an excellent locality at which to observe the relations between schist and amphibolite, the linear ridges of schist and quartzite striking squarely against the north face of the amphibolite, and being as squarely cut off by it. The quartzite in this belt is interbedded with impure limestone and with hard, fine-grained mica-gneiss of general dark gray color. In the comparative abundance of quartzite and the scarcity of the green, pyroxene gneisses which abound in belts nos. 2 and 3, this belt no. 1 contrasts rather strongly. The subsidiary ridge in this belt, the schist ridge which is cut out at the north by the granite at Osborn lake, consists chiefly of hard, mica-gneiss.

The narrow southern end of belt no. 2 also consists largely of hard mica-gneiss with interbedded thin quartzites, with an occasional thin limestone band, quite like the previous except that there is less quartzite. There are also occasional bands of the impure, hematitic quartzites, which weather readily, and which are common rocks in the Grenville in many localities. With the broadening of the belt to the northeast, while still consisting largely of mica-gneiss, beds of white, red or green, fine-grained, hard pyroxenic gneisses come in also in considerable bulk. There are also beds of very black, very dense, very fine-grained mica-gneisses, which resemble amphibolite, but prove to hold no hornblende. They are probably regular members of the sedimentary series.

In belt no. 3, especially in the northeast portion of the quadrangle, where it is broad, there is a great development of these green and red pyroxene gneisses, although beds of quartzite, mica-gneiss and impure limestone are always present.

In all these belts one surprising character of all the gneisses is the universal presence of tourmaline as a constituent, often in quantity. Tourmaline in pegmatites and in contact zones is also present, but is not here referred to, the tourmaline being disseminated through the gneiss as a regular constituent. It is sometimes black, sometimes brown, sometimes dark green, sometimes white (colorless in thin section). The crystals are usually very tiny and in general not to be made out except in thin section under the microscope. Out of forty thin sections of various types of these gneisses, twenty-five contain tourmaline: in ten it is black, in eight brown, in
four green and in three it is white. In the green schists in Alexandria, to which structural reference has already been made, and which are very similar rocks, if not the same identical formation as these schists of Gouverneur, tourmaline is a frequent minor constituent; but it is present there in nothing like the force that it is here. In the rock cliff on the south side of the river at Rock Island bridge is a great band of very hard, fine-grained, gray-black rock which is a quartz-feldspar-tourmaline rock, in the proportions of 10 per cent quartz, 40 per cent microcline and 50 per cent tourmaline. This is, of course, an exceptional rock, but in several other cases the tourmaline constituted from 5 to 15 per cent of the rock. It is present in much greater quantity than in the Alexandria rocks, and its abundance rather reinforces the conclusion arrived at in accounting for the mineralization of the limestone at the Richville brown tourmaline locality already described, the probable presence of a large mass of porphyritic granite below ground, from which mineralizing solutions have worked their way upward, and prominently affected these schists.

A ridge of hard, dense, red gneiss, of alternating very fine-grained broad bands and narrow, coarser-grained ones, crosses the state road 2 miles north of Richville. The rock is chiefly a feldspar-brown tourmaline combination. The fine-grained bands consist of an intimate, half and half mixture of brown tourmaline and feldspar (probably albite) with frequent tiny rutiles and an occasional pyrite. The coarser bands consist chiefly of albite but hold occasional tourmalines. The rock as a whole contains about 35 per cent of tourmaline.

The general run of these pyroxene gneisses are of green color and contain from 25 to 35 per cent of pyroxene of varying shades of green. Titanite is a very abundant accessory mineral in nearly all of them. Sometimes epidote and actinolite are present also, but more usually they are not. The very pyroxenic rocks contain little or no quartz, while those with less pyroxene carry from 5 to 15 per cent of that mineral. The feldspar varies much in the different varieties; it is usually plagioclase—albite to andesine—but often much microcline is present. Scapolite is a very common constituent.

The red rocks are much poorer in pyroxene than the green and consist largely of feldspar and scapolite, with tourmaline and rutile, and in general with a high degree of alteration in such pyroxenic constituents as are present. The interbedded quartzites and mica-gneisses also contain frequent tourmaline. On the state road, a half mile north of the red, tourmaline gneiss just described, is a cut in
rasty gneiss full of pyrite. Otherwise the rock is firm, white and fine-grained, and consists of a feldspar-quartz mosaic with a little mica, frequent small rutiles, and quite abundant white tourmaline.

The mica-gneisses are, in general, firm, fine-grained rocks, quite resistant to weathering, in part with the mineral constituents pretty evenly distributed, in other part banded rocks, dark-colored micaceous bands alternating with white ones nearly free from mica. They are quartz-feldspar-mica rocks, the mica chiefly phlogopite, the feldspar microcline or microcline and acid plagioclase in varying proportions. The feldspar may greatly exceed quartz or the reverse may be true, the relative quantities of the two varying much from place to place. Titanite, zircon and apatite are usual accessories, while graphite often, rutile sometimes, and tourmaline in many instances occur. With these usual gneisses are frequently very micaceous beds which weather with great rapidity, and hence seldom show well in outcrop except in rock cuts of recent make.

There are other very micaceous beds which are much more resistant and much resemble amphibolites, and such beds are sometimes present in bulk. In part they rudely resemble "augen gneisses" owing to the development of small rounded areas which are much poorer in mica and hence of much lighter color. These are biotite, rather than phlogopite rocks, and the mica constitutes from 25 to 50 per cent of the rock. Tourmaline, usually of dark green color, is often present in abundance, while apatite and pyrite are the most prominent accessories. Quartz does not in general exceed 10 per cent of the rock, and the feldspars are acid plagioclase and microcline.

All these mica-gneisses are quite certainly metamorphosed shales, while the pyroxene gneisses are derived from calcareous shales and very impure limestones.

These gneisses show such manifold variety that it is an almost impossible matter to give a good general description of them. In the Edwards belt they are much cut by dikes of aplitic granite and by amphibolite, but otherwise are of the type just described. In all the belts much of the gneiss is strongly altered. Certain of the minerals in many of the slides show a mere jumble of alteration products, so that the original mineral can not be definitely made out, and this is particularly the case in the Edwards belt. Moreover, the alteration is not of the type produced by weathering, but of the pneumatolitic type, and thus reinforces the suggestion already made that the schists have been strongly attacked locally by solutions arising from granites below ground.
Rusty Gneisses

The rusty gneisses are those members of the general gneiss series, either quartzites or quartz-mica-gneisses, in which pyrite is so largely developed that the rock weathers and crumbles readily and takes on a rusty appearance in outcrop. Such rocks occur within the quadrangle in three different ways. They are found interbanded with the hard gneisses, interbanded with the limestones, or as marginal bands separating limestones from adjacent igneous rocks. In the latter case their situation suggests that they may be contact rocks, but such a conclusion is of course forbidden by the character of the rock itself, and by the fact that identical rocks occur within the Grenville away from the intrusives. It is, however, true that a selvage of rusty gneiss between granite and limestone is such a common feature of the geology of the quadrangle as to strongly reinforce Smyth's suggestion that much of the concentration of pyrite in the rusty gneisses of the region is due to the action of circulating solutions which were in part at least of magmatic origin.¹

The general rusty gneiss is a siliceous quartz-feldspar rock with but little mica, and with much pyrite. At the surface the pyrite rapidly weathers and disappears and the rest of the rock either breaks down or becomes porous and cavernous and stained by iron oxide. There are several belts of the rock within the quadrangle. They are:

1 A narrow belt, about 5 miles long, runs from west of Sylvia lake to Fowler, lying between limestone on the east, and amphibolite and granite on the west. At Fowler it is cut out by amphibolite but what seems to be the same band reappears to the west of Talcville for a short distance and then is cut off by granite.

2 The narrow belt of hard gneiss at the western edge of Gouverneur village consists largely of rusty gneiss. Cut out by granite it reappears again on its east edge and the rusty gneiss forms the easterly margin of the band of hard gneiss there mapped, becomes very prominent at the Cole mine, and continues thence to the northeast all the way to the Stella mine at Hermon on the next quadrangle, where it becomes involved with amphibolite. It is thus the longest continuous band within the quadrangle.

3 There is a considerable belt of rusty gneiss in the extreme northwest corner of the quadrangle. On the Ogdensburg sheet it quickly disappears under the Paleozoics. The southwest, on the Hammond sheet, its extent has not yet been mapped.

¹ N. Y. State Mus. Bul. 158, p. 170-82.
A band is associated with the amphibolite at Halls Corners, where it pinches out in limestone at the north end of a pitching syncline. Each limb of the syncline has a long extent on the Hammond sheet, as recently shown by Buddington, the two limbs constituting his Laidlaw and Keene-Antwerp belts.¹

The great knob of sharply pitching gneiss just northeast of Pleasant Valley School, southeast of Talcville, has a strong band of rusty gneiss.

In addition to these chief bands rusty gneiss outcrops in a host of other localities within the quadrangle, as inclusions in the igneous rocks, as narrow selvages between limestone and granite, or in belts too narrow or too short to warrant attempts at separate mapping.

Garnet-Gneisses

In his report on the Precambrian Rocks of the Canton Quadrangle, Martin gives a very full discussion of the garnet-gneisses encountered on that area.² He discusses these rocks under three types:

First that which forms the greater part of the large S-shaped fold found in the southeast corner of the quadrangle; second, the long, narrow bands of garnetiferous rock which are characteristically associated with the periphery of areas of granite-gneiss; third, all other occurrences, found independently of the first two types and interbedded with typical Grenville sediments.

On the Gouverneur quadrangle these rocks have a much greater areal distribution even than on Canton, and it will facilitate our discussion of them to follow his subdivisions of type. It remains to be stated that the two great areas of garnet-gneiss, the one to the south and the other to the north of Edwards, and in addition the narrower belt in the center of the quadrangle, running from the sheet margin south of Gouverneur up to Moss ridge, belong distinctively to his first type; that representatives of the second type are numerous, a notable instance being in the case of the narrow but very long inclusion of garnet-gneiss and limestone within the granite along Tanner creek in the east portion of the quadrangle; and that representatives of the third type, thin bands of garnet-gneiss interbedded with other Grenville sediments, are practically nonexistent on the Gouverneur quadrangle.

These garnet-gneisses are quite characteristic members of the Grenville series in northern New York, particularly in the southern

¹ N. Y. State Defense Council Bul. 1, p. 3.
² N. Y. State Museum Bul. 185, p. 24-40.
and western parts of the region. The writer has not met them in anything like the same prominence on the east and north; but those are the districts where the intrusives greatly predominate and there is much less Grenville than on the south and west. Our impression is that garnet-gneiss is much less conspicuous as a Grenville member in the northeast half of the region; but we are not sufficiently sure of the correctness of this position to wish to emphasize it too strongly.

The extensive masses of garnet-gneiss of the first type will be shown to be, structurally, the lowest member of the Grenville series represented within the quadrangle. They rest either upon igneous rock or on sediments which are nowhere exposed at the surface. Nowhere are they pure sediments but on the contrary are quite typical injection gneisses, being everywhere shot through with lit-par-lit granite and pegmatite bands (plate 4). From these bands cross-cutting dikes radiate, and from them also material has worked its way into the remainder of the rock, which is everywhere more or less granitized, though the degree of this varies much from place to place. The general rock has a dark gray color, while the granitic bands are usually white, more rarely red, so that the rock as a whole is usually strongly color-banded. The light-colored granitic bands vary greatly in abundance, rising to as high as 50 per cent of the rock, and falling to 5 per cent or less. Often their boundaries are subparallel for considerable distances so that the banding is very regular; equally often it is quite irregular. Certain of the granite and pegmatite films show very sharp, even boundaries against the adjacent gneiss; others as constantly break out into and impregnate the gneiss with granitic material.

The typical garnet-gneiss consists of quartz, feldspar and mica. The quartz content varies from 10 to 33 per cent, with an average of from 20 to 25 per cent. The feldspar is chiefly alkali feldspar, orthoclase or microperthite with some microcline, but there is always some and often much plagioclase, usually oligoclase, in addition. The usual mica is biotite, but sometimes phlogopite replaces it. The granitized and nongranitized bands have the same mineralogic make-up, and their chief composition difference consists in the abundance or scarcity of the mica, which is abundant in the gneiss and scant in the granite. Garnet, titanite, zircon and pyrite are the universal accessories. The garnets occur throughout most of the rock, although in very varying quantity. Although they have a considerable range in size, they are for the most part small, and of a
pinkish shade instead of deep red. When large they are often skeleton crystals, full of inclusions, but this is not prominently the case with the usual small ones. They seem in all cases to have been the last mineral to form and likely to have resulted from the action of the granitic on the shaly material, notwithstanding the fact that they occur scattered through the whole rock, both the granitic and the gneissose portions. As a whole, however, they are much more abundant in the latter than in the former.

Besides the ordinary variety of garnet-gneiss, injected with white granite and pegmatite, there is also a nongarnetiferous variety, of the same mineralogy as the other except for the lack of garnet. Much of the injecting granite which ribbons this rock is red instead of white, and as a whole it does not carry so much granite as does the other. It occurs in part in small thickness interbanded with the garnetiferous variety, and in part in large thickness with less intermixture of the other. It is found in large thickness in the extreme southeast portion of the quadrangle east of Bonner lake. Excellent localities showing the intermixture of the two varieties may be seen along the Trout lake road, just west of the lake and also farther north.

These garnet-gneisses are widespread in northern New York. They are abundant all along the south margin of the Adirondacks and, in reporting upon them in the Saratoga region the writer argued that they were injection gneisses, the white bands being of igneous origin. Martin holds the same view for these rocks on the Canton quadrangle. The original rock must have been a shale and only slightly calcareous, since the present rock holds very little lime. The shale has been metamorphosed to a mica-gneiss, and thoroughly penetrated and impregnated by injected granitic and pegmatitic material.

The garnet-gneisses of the second type are such as occur as selvages between limestone and granite, in imitation of contact zones. The great inclusion, 5 miles in length, within the granite which lies along Tanner creek in the east-central portion of the quadrangle and consists of central limestone with a continuous border of garnet-gneiss on each side, is the most conspicuous example found, although others are frequent. The long belt of the gneiss which runs diagonally across the quadrangle from southwest to northeast and wraps round the south end of Moss ridge in complicated fashion, and which lies between granite on the east and limestone on the west, is another example, but not so striking as that of Tanner.

Garnet injection gneiss from exposure by the Trout Lake road 1 mile south of Trout Lake School, the light colored bands being of white granite and the darker ones of mica-gneiss. Garnets are too small to show plainly and are not abundant. The first band of mica-gneiss on the left is considerably soaked by granite, and the granite band on the right contains much gneissic material.
creek. The position of such belts definitely suggests their contact nature, but the writer is in entire agreement with Martin who holds that they can not be regarded as contact rocks. The rock is precisely like that in the belts of the first type, where there is nothing to suggest a contact origin; the boundary of the garnet-gneiss against the limestone is always sharp, with no sign of the gradation of one rock type into the other which would normally be expected were one a contact form of the other; neither is the mineralogy of the garnet-gneiss that of a limestone contact rock, aside from the garnets. The gneiss is practically free from lime. As a result of microscopic analysis, it may be confidently stated that it contains probably less than 2 per cent of calcium on the average; and it is difficult to conceive of any process whereby a limestone could be converted into such a rock. In the granite are many inclusions of limestone, both large and small, which show no sign of garnet-gneiss borders; there are also many inclusions of garnet-gneiss with no sign of limestone. We are therefore driven to the conclusion that the garnet-gneisses of the second type owe their position to purely structural causes, that the gneiss is an integral member of the sedimentary series of Grenville age and underlies the great limestone, that the Tanner creek inclusion is a syncline pinched in the granite, with the lower portion of the limestone formation folded down into the upper beds of the gneiss, and that the long garnet-gneiss belt diagonally across the quadrangle center lies in the east limb of a syncline with the gneiss in normal position underneath the limestone.

The question naturally arises why these particular gneisses are so thoroughly penetrated and impregnated by granite, in contrast with the other Grenville sediments. It is the common experience in the region that all garnet-gneiss areas, and most of those of amphibolite, are full of veins and sheets of granite and pegmatite, and readily undergo granitization, passing into the category of soaked rocks. In this respect, these two rock types are in sharp contrast to all other rocks of the region. No explanation seems to meet the conditions observed except the one that ascribes the easy penetration of these two rocks by granite chiefly to their original highly developed cleavage. The garnet-gneisses are metamorphosed shales, and in their recrystallized condition have a large mica content and are well foliated. Their thorough injection by granite is of the lit-par-lit type, penetrating along the cleavage planes. With the exception of certain hornblende gneisses, which
are subject to the same sort of granitization, none of the other common Grenville rocks, limestones, quartzites or hard gneisses, have a good cleavage. Instead of being intricately and minutely penetrated by granite everywhere, these sediments resist such action, and are found cut by occasional large dikes, sheets or stocks of granite instead of showing the intimate penetration which the garnet-gneiss exhibits.

Martin has called particular attention to the plasticity of the garnet-gneisses under pressure, as shown by their intricate folding and puckering, so that they seem to be second to the limestones alone, among all the rocks of the region, in this property. Our own observations are in entire agreement.¹

Variants from the general type of garnet-gneiss occur locally. Just east of Hailesboro the state road from Gouverneur to Fowler cuts through a low ridge of gneiss, near the west edge of the garnet-gneiss belt there, which departs from the normal type and is a very unusual and handsome rock in appearance. It is the ordinary injection gneiss though less injected than the average of the garnet-gneiss, but in addition it contains a great number of narrow, lenticular white bands of such fine grain as to give them a typical stony appearance, and also frequent, large garnets, of a purplish, almost amethystine color. These white bands are in strong contrast to the white granite sheets of the gneiss in their narrowness, their shortness and their fine grain. The garnets are of lenticular shape, elongated in the foliation planes, and are always in association with the white, stony bands, such bands always tailing away from one or both ends of the lens of garnet. No garnets were seen separate from the white bands, although many of the latter contain no garnets. In thin section the white bands are seen to consist of a felt of tiny sillimanite needles with interstitial quartz, the two in about equal quantity, and with abundant tiny zircons. The rock has not only been much squeezed, but was under much compression while the garnets were forming, as their shape shows, and the association of garnet and sillimanite bands suggests the possibility that the latter have arisen at the expense of the garnet, and that in the case of the bands in which garnet is lacking, it is because of its entire conversion to sillimanite. Such a conversion would, however, be most difficult to account for chemically, and probably the association is fortuitous, both being due to recrystallization along the foliation planes in a rock under high pressure. In plate 5 a view of a hand specimen of this rock is shown.

Garnet-gneiss from cut by Gouverneur-Edwards state road, just east of Hallsboro, with large garnets. It is not much injected by granite and the white bands are composed of an intimate mixture of quartz and sillimanite.
Another type of gneiss found here and there in the general garnet-gneiss series contains less mica than the usual rock and in its stead carries considerable hornblende and pyroxene, and small garnets are more numerous than in the ordinary rock. Such rocks have probably arisen from bands of the shale which were originally more calcareous than the general run of the rock. In such a great thickness of clay shale as is represented in metamorphosed condition by the garnet-gneiss group, occasional beds with somewhat more lime content than the normal are to be expected.

**Contact Garnet-Gneisses**

Garnet-gneiss which is unmistakably of contact origin is found adjacent to some of the granite of the quadrangle. Such rock is best and most persistently shown along the east and southeast margin of the granite of the Reservoir hill sill, east of Gouverneur. The zone of contact rock is very narrow, in general from 1 to 5 feet in width, lying between the granite and the adjacent limestone. Along a portion of the east margin it widens considerably but even here it can not be mapped without exaggeration. The rock differs from the ordinary garnet-gneiss in having little or no foliation, in the abundance of good-sized garnets, which are generally of the skeleton type, and in the presence of pyroxene, tourmaline and pyrite, the whole making a rock of high specific gravity. It is frequently soaked by granite but, owing to poor foliation, the granite attack is very irregular instead of being of the even *lit-par-lit* type.

**Amphibolites**

Hornblende gneisses of sedimentary origin, of contact origin, and of igneous origin occur throughout the Precambrian mass of northern New York. In the Gouverneur area only the latter type is found in quantity. The sedimentary gneisses of this sort occur as beds, usually thin, within the belts of hard gneiss, of limestone and of garnet-gneiss, very frequently in the first case, much less often in the others. They are found in many localities within the quadrangle but their aggregate thickness is not great. It is possible of course, that some or all of these seeming beds of hornblende gneiss may actually be of igneous origin, representing metamorphosed thin sheets of gabbro. In the great majority of cases, however, this seems most improbable. The contacts in many cases are not unduly sharp; no signs of cross-cutting have been
seen at any contacts as would surely be the case sometimes were these true igneous sheets; and there seems to be no relationship between the occurrence of such beds and the proximity of nearby masses of gabbro-amphibolite. They are just as abundant at a distance from such masses as they are in their vicinity. Moreover, these sedimentary amphibolites seem to have a slightly different facies from those of igneous origin, although this is more easy of recognition than of description. The igneous ones are apt to have a more massive look, and sheetlike bands of supposed igneous origin are also found in the sediments, more particularly in the vicinity of the larger igneous masses.

Very little amphibolite to which a contact origin may be definitely assigned has been noted within the Gouverneur quadrangle.

**IGNEOUS ROCKS**

**Gabbro-Amphibolite**

The metamorphosed gabbros classed under this heading occur abundantly within the quadrangle and also to the north on the Ogdensburg quadrangle, but in many respects they are exceedingly puzzling rocks. They are everywhere closely involved with the porphyritic granites, occurring as frequent inclusions in them or themselves all cut to pieces by sheets and dikes of granite and dikes of pegmatite, and with the production of much soaked rock; that is, much of the granite contains more or less partly digested amphibolitic material, and much of the amphibolite itself is intensely granitized. A large part of the amphibolite is now really a coarse injection gneiss. Nearly all of the masses of this rock are bordered by granite on at least one side, and the gradation from one rock to the other is so intimate that the boundaries mapped between them are in the highest degree conventional. This is especially true in the case of the two largest masses of amphibolite within the quadrangle; the one which comes in at the southwest corner and runs northeast and east through West Fowler and Emeryville nearly to Talcville, together with its subsidiary masses to the southeast in the Fullerville region; and the other the masses which flank the Maple ridge granite in the northern part of the quadrangle. In each case the granite becomes more and more packed with amphibolite inclusions, and the amphibolite is cut by constantly more numerous and larger sheets and dikes of granite, as the border is approached, and the mapping of the boundary is based upon the estimate by the individual geologist of the line where the two rocks
are in about equal quantity, with granite in excess in the one direction and amphibolite in the other. Obviously such a mapped boundary must depend in large measure on the individual judgment of the geologist; it must also be highly irregular. Hence there are portions of areas mapped as granite in which amphibolite actually exceeds granite in quantity, and amphibolite areas in which granite is in excess. It is also true that some boundaries are much sharper than others and can be readily mapped with a close approach to accuracy.

As mapped, the amphibolite masses seem to be either sills or stocks, the larger ones all belonging in the former category. Perfectly evident is the sill-like structure of the long, narrow mass which comes down from the Ogdensburg quadrangle, forms the western portion of Maple ridge, then passes down through North Gouverneur and north of Halls Corners and thence southwest on to the Hammond quadrangle. It is long and narrow and strikes and dips with the associated rocks. The similar structure of the West Fowler-Emeryville mass is equally evident, although this is not so long as the other, is associated with granite for its entire length, and curves back upon itself at its northeast end. There are also several smaller sills, each of which is associated with a granite sill. Other masses, however, such as that southeast of Fowler, that in the northwestern part of the quadrangle between the two branches of Beaver creek, that between East De Kalb and Old De Kalb, and that in the extreme northeastern part of the quadrangle, which runs over to the Stella mine at Hermon on the next quadrangle, are more or less broadly oval in ground plan and seem properly to be classified as stocks. Some of these wholly lack contact with granite, at least at the present-day surface.

All of these gabbro masses are highly metamorphosed and consist in large part of very micaceous hornblendic gneisses, full of quartz and pegmatite veins and blebs, much cut and soaked by granite and pegmatite, and thoroughly foliated. There are, however, abundant cores of much more solid amphibolite, with little or no foliation, whose massiveness leaves small doubt in the mind of the observer as to the igneous nature of the rock. The cross-cutting character shown frequently (more particularly by the stocks) furnishes the definite proof. This feature is beautifully shown at both the north and the south fronts of the stock in the northwest corner of the quadrangle, just east of Huckleberry mountain. The numerous, linear ridges of schist and quartzite to the north of the stock strike directly against its north face and, over a distance
of a mile, are squarely cut off by it. The limestone to the south
does not show the relation as plainly, outcrops being fewer and
foliation poor, but it is also squarely cut off across the strike.

In these old gabbro-amphibolites of northern New York it is
usual to find uncrushed cores of the rock which consist of pyrox¬
ene, hornblende and plagioclase feldspar (andesine to labradorite
or bytownite). These grade into equally massive rocks in which
the pyroxene has disappeared by alteration into hornblende, and
the rock is a hornblende-plagioclase rock, with more or less black
mica. These massive amphibolites grade, in their turn, into schis¬
stone varieties, with increasing amount of mica, and with it some
quartz and alkali feldspar. Martin has described such pyroxenic,
uncrushed gabbro cores from the identical rocks of the Canton
quadrangle.¹

None of the specimens of massive amphibolite collected by us
on the Gouverneur quadrangle shows any trace of unaltered mono¬
clinic pyroxene, but two specimens do show what seems to be
wholly altered hypersthene. There is little doubt that pyroxenic
varieties do occur within the quadrangle; but even without them
there can be no question that the masses of solid amphibolite are
altered gabbros, in which the original pyroxene has altered to horn¬
blende, and the hornblende in its turn has begun to alter to biotite.
They are essentially hornblende-plagioclase feldspar rocks (labra¬
dorite), with accessory apatite, ilmenite, zircon, biotite and pyrite,
and often titanite, the feldspar constituting from 50 to 70 per cent
of the rock in the various occurrences. Some biotite is always
present and it rapidly increases in amount as the rock becomes more
gneissoid. At the same time, the grain of the rock becomes broken
down, the large feldspars becoming more and more granulated at the
margins, with the uncrushed cores always under strain, while the
hornblendes fray out into biotite scales. With these, quartz
and some microcline or other alkali feldspar appear, and the rock
as a whole is more siliceous. Martin’s plate from the Canton
quadrangle shows well the contrast in appearance between the
massive and schistose varieties (plate 6), even though the one is
injected by granite.

Since with this increasing schistosity injection and soaking by
granite go hand in hand, it is often difficult to determine how much
of the change in chemical and mineralogical composition is due to
mere metamorphism and how much to the granitization. That the

¹ N. Y. State Mus. Bul. 185, p. 57, 61.
Upper figure. Mixed rock; typical example of modification of amphibolite by granite. Admixture here is extreme and not common. About one-eighth natural size.

Same location as shown in plate 11, lower figure; 1.3 miles southwest of Pierrepont.

Lower figure. Typical black amphibolite or hornblende gneiss; seamed with minute veinlets of hornblende (weathering in relief), the whole then cut by irregular masses of pegmatite. Scale about one-tenth natural size.

One and four-tenths miles east-northeast of Beach Plains Church, about 75 yards east of road.
formation of biotite and quartz from the hornblende goes on due to metamorphism solely, is unquestioned. The highly siliceous varieties of these mica-gneisses are always heavily granitized, but are mapped as gabbro-amphibolite even when their silica percentage approaches that of granite, since the amphibolite was plainly the original matrix of the rock.

These gabbro-amphibolites are the oldest igneous rocks of the region, being cut by, and occurring as inclusions in, all the granites. If the writer's belief that there are two granites of widely different age in the district be the correct one, the statement is still true, all the granite showing itself to be younger than the gabbro.

The most prominent features of these rocks are their susceptibility to granitic attack, and their close association with abundant granite nearly everywhere. The similar susceptibility of the garnet-gneisses has already been noted as well as the contrast with all other rocks of the district which both rocks show in this respect. Every amphibolite sill in the region is bordered by a granite sill, with a broad zone formed of an intimate commingling of the two rocks along the contact which defies exact mapping. Every amphibolite mass consists largely of very micaceous gneiss, intimately attacked by the granite. In discussing this phenomenon as found in the garnet-gneiss, it was argued that the high degree of schistosity of the rock was in large degree responsible for the ready attack upon it by the granite and the large scale formation of injection gneiss. Injection gneisses are coarser and ruder in the case of the amphibolite; the rock does not lend itself to the formation of such intimate lit-par-lit injection as the garnet-gneiss does. On the other hand, the granite minutely penetrates the amphibolite, with formation of soaked rock, more readily even than it does the garnet-gneiss. In the case of the amphibolite, it is thought that the composition of the rock gives an added reason for the granite attack upon it, the schistosity not being the sole reason. Both are igneous rocks; the granite is very probably a differentiate from a gabbro magma, and would therefore readily attack and assimilate gabbro material. It is also true that the mica-gneisses which have been converted into garnet-injection-gneisses have a composition sufficiently similar to the amphibolite to have permitted their ready soaking by the granite. Why the granite sills tended to select the contacts between the gabbro sills and the Grenville for their own lines of intrusion is not exactly obvious, but the fact that in the great majority of cases
they did thrust in along precisely such situation, points to such contacts as unmistakably the zones of least resistance. The granite injected itself where the task was easiest; hence the contacts between the gabbro sills and the Grenville evidently furnished less obstacle to the intrusive forces in general than did the boundaries between the different Grenville formations, or the planes of separation between beds of the same formation.

Granites

In the great Precambrian area of Canada the present-day surface is much more widely occupied by granite than by any other rock. These granites occur in masses of all sizes but many of them are very large, seem to extend downward indefinitely, and are therefore classed as bathyliths. The Canadian geologists have long recognized that these granites were not all of the same age and have classed them in at least two groups according to this age difference. More recently a disposition has been apparent to recognize granites of three different ages.

In the smaller Precambrian district of northern New York granite does not bulk as large as in Canada and other intrusive rocks play a larger role, yet in New York also probably granite is more widespread than any other rock. Owing to the general similarity of the New York and Canadian districts, it would be natural to expect that granites of more than one age would be found in New York also.

In reporting upon the Geology of the Thousand Islands Region some years ago, Cushing showed that there were present on the Alexandria Bay and Grindstone quadrangles two granites of widely different age, the older of which was classed as Laurentian in accord with the Canadian usage prevailing, while the other was called the Picton granite. A third granite was also present on the Alexandria Bay quadrangle, but in only small quantity and in close relation to a red syenite, the Alexandria syenite. In contrast to the other two this was a porphyritic granite. It was unmistakably younger than the Laurentian granite, but its age relation to the Picton could not be definitely ascertained, although the Picton was found to hold inclusions of a porphyritic granite of similar type.¹

In subsequently reporting upon the geology of the Ogdensburg and Brier Hill quadrangles Cushing showed that the extreme northeast point of the Alexandria granite bathylith of Laurentian age

was found in the southwest corner of the Brier hill quadrangle, beyond which its possible further extent was hidden from view under a cover of Potsdam sandstone; and that in the southeast portion of the same quadrangle was another considerable mass, called the Macomb granite, which perhaps was a part of the Alexandria batholith from which it was separated by Paleozoic rocks only, in any case, a closely outlying body and probably of the same age, although definiteness in the matter was impossible. It was also shown that there was a large body of granite in the southeast portion of the Ogdensburg quadrangle, the De Kalb granite, which extended south to Gouverneur and east to Canton, and which, while recalling the Laurentian granites in many respects, showed some puzzling and abnormal features; hence it was tentatively suggested that the mass was a combination of granites of two different ages, in part Laurentian and in part later. It was further shown that there were present in the southern part of the Ogdensburg quadrangle a number of sills of porphyritic granite of the same type as that connected with the syenite on the Alexandria Bay quadrangle, and also of the same type as the porphyritic granites which occur widely as a differentiation phase of the syenite bodies in northern New York. These granites were classed separately from the others and regarded as most certainly younger than the Laurentian. The relations shown were so obscure, however, that detailed consideration of them was left until the mapping of the Gouverneur sheet was completed, in the hope that further light would be shed upon them.

The Picton granite of the Thousand Islands region is a rather coarse-grained, nonporphyritic, red granite, which shows little sign of mashing, or of metamorphism, and in these respects as well as in its demonstrable field relations to the granite-gneisses regarded as Laurentian shows itself to be unmistakably younger. The fact that it also holds inclusions of porphyritic granite is evidence that it is younger than that rock. The porphyritic granite in its turn seemed surely a border phase of the syenite whose younger age than that of the Laurentian was shown along the western and southern sides of the syenite where it is in contact with granite gneiss for a distance. It both cuts it out across the strike and holds inclusions of it, just as it does with the adjacent Grenville beds.

No granite at all comparable with the Picton is found on the Gouverneur quadrangle, or on Ogdensburg and Brier Hill for that matter. Porphyritic granite, however, abounds on Gouverneur, and the older Laurentian granite is believed to be present, although the evidence is far from decisive, since the two rocks do not occur
in contact as far as it is known. The belief in age difference is based on the different character of the two rocks, and their apparent identity with similar rocks on the Alexandria Bay quadrangle. The differences in character are as follows:

The granites classed as Laurentian are always thoroughly gneissoid, generally of fine and even grain, usually with very small mica content except where they have obviously soaked up amphibolite material, seldom if ever porphyritic, and containing amphibolite inclusions, often in great number, but with few or no other kinds of inclusions.

The porphyritic granites, on the other hand, are often coarsely porphyritic although they show also fine-grained, nonporphyritic phases which are often difficult to distinguish from the previous type; their mica content is usually large instead of small; while holding amphibolite inclusions in abundance they contain also many inclusions of the various Grenville rocks, even those of limestone; the types of inclusions held show a much more marked kinship with the bordering rocks than in the other case where the inclusions tend to monotonous amphibolites; and in many districts the porphyritic granites show a definite relationship with syenites, while such a relation is seldom, if ever, clearly shown in the case of the Laurentian granites. In addition, in the Gouverneur region, the porphyritic granites occur exclusively in sills, and the nonporphyritic occur as cross-cutting bodies.

On the basis of such differences the writer rather confidently classes the granite mass which lies directly north of the village of Gouverneur as Laurentian. All other granite of the quadrangle belongs clearly to the porphyritic group except for the De Kalb granite. The southern edge of this mass appears in the northeastern part of the quadrangle, whence it runs widely on to Ogdensburg and Canton. On the latter quadrangle in particular it has a sill-like form. While in doubt as to the proper grouping, his present opinion is that the mass is likely a combination of the two types of granite. If not, it should be classed with the Laurentian, in spite of its sill structure.

**Gouverneur Granite**

This name may be conveniently applied, for local use, to the granite mass just north of Gouverneur, an oval-shaped mass with northeast trend, and a long axis of about 5½ miles and average breadth of 1½ miles. It is for the most part surrounded by lime-
Amphibolite inclusions in Laurentian granite-gneiss, in exposure by the roadside 1 mile north of Gouverneur on Peabody Bridge road. These inclusions are mostly sharp, and not greatly soaked, but are much drawn out, in some cases ruptured and separated, and in the case of the large inclusion near the top, cut in very complex manner by the granite.

North edge of Gouverneur granite mass, 1 mile south of Rock Island bridge.
stone, the only exception to this being a couple of thin bands of hard schist within the limestone, which border the granite for a distance. The limestone is very massive and hence it is difficult to ascertain whether the granite is really a cross-cutting body or not. At the south, however, it certainly cuts out a band of hard gneiss and it seems clearly a small example of the generally oval bodies of granite of the bathylith type that prevail in the region, all of which are elongated in the general northeast direction of the strike owing to compression, and few of which show any tendency in the strike of the adjacent sediments to wrap round the ends.

This particular granite consists throughout of a quite fine and even-grained orthogneiss, consisting chiefly of feldspars and quartz with a very small mica content. It shows frequent coarser bands and frequent pegmatites, which diversify it somewhat but nevertheless are not in sufficient quantity to greatly affect its usual uniform and monotonous character. Inclusions are frequent but very unequally distributed and are almost without exception of amphibolite. These show the usual effects of granite action, being in all stages of elongation, of breakage and of soaking and absorption by the granite (plates 7 and 8). Toward the margins, near the limestone, the granite nearly everywhere turns from red to white in color, exhibiting precisely the same bleaching effect of limestone upon red granite that was described from the Thousand Islands region, although the white granite zone here is much narrower than that margining the Alexandria granite. The numerous granite dikes and plugs that cut the limestone are of white granite in every case seen, and are usually of coarser grain than the general body of the rock. There are several of these white granite knobs in limestone at the southwest end of the granite mass, just over the border on the Hammond sheet. There are others near Richville, also in limestone, which are on the trend of the major axis of the granite body and which, although at quite a distance from the main mass, are quite confidently classed with it.

The one considerable exception to the rule that the inclusions consist of amphibolite, occurs 2 miles north of Gouverneur on the Peabody bridge road, where there is a large inclusion of Grenville gneiss of the garnet-gneiss, mica-gneiss type, with a little interbanded limestone. This is the type of Grenville rock most likely to be incorporated in the granite without material change in character.

Our belief is very strong that this granite mass is old, is of the same type as that of the Alexandria Bay bathylith, and is to be classed with it.
Granite Sills

The granites of Huckleberry mountain, Maple ridge, Moss ridge and Reservoir hill are all sills, intruded into the Grenville sediments parallel to the bedding, and in the same category goes the great granite mass which runs diagonally across the quadrangle from southwest to northeast, together with its outlying tongues to the southeast. This great sill may be conveniently called the Hermon-Fowler sill, or for brevity the Hermon sill, because the greater part of its mass lies in that township.

The rock of these sills is of two somewhat contrasted types. The Hermon and Maple ridge sills are mostly composed of coarsely porphyritic granite, coarsest at the margins. But the granite of Huckleberry mountain, Moss ridge and Reservoir hill is comparatively fine-grained, with only traces of porphyritic texture. In fact, it more closely resembles the Laurentian granite than it does the usual porphyritic variety. Inclusions are few and the granite is very clean and homogeneous. The Reservoir hill granite is entirely inclosed in limestone, except for a narrow selvage of garnet-gneiss on its eastern border; the Moss ridge sill is narrow and intruded along the contact between limestone and garnet-gneiss except at its south end where it has garnet-gneiss on both sides and is sharply infolded with it; the Huckleberry mountain sill has limestone on both sides except at the north, where the limestone pitches down under quartzite and mica-gneiss and the granite is in contact with these.

The Hermon and Maple ridge sills contrast sharply with the others in having amphibolite on one contact. The amphibolite has been attacked with great energy by the granite, and a belt of soaked rock, often very wide, lies between the two so that no accurate boundary can be mapped. The Hermon sill abounds in inclusions, large and small, both of amphibolite and of Grenville, and these show also sharp contrast in respect to granite attack. The amphibolite inclusions are strongly attacked, those of limestone not at all or but little. The garnet-gneiss inclusions are of the usual injection gneiss, quite like the garnet-gneiss elsewhere. The identity suggests that these rocks had been converted into injection gneiss long before the intrusion of the granite of the sills.

Just what the relationship is between the soaking up of amphibolite by the granite, and the development of a coarsely porphyritic texture in the latter rock, it is difficult to say, but the field facts are decisive as to the relationship. That the rock of all the sills is of about the same age and consists of the same granite seems to us
beyond question. In the sills which border amphibolite, however, the entire granite has incorporated amphibolitic material, the rock everywhere carrying much black mica, and often hornblende in addition, the two constituting from 10 to 20 per cent of the rock instead of the 5 per cent or less which is the mica content of the granite of the other sills. The granitized amphibolite is also full of large, porphyritic feldspars, and occasional ones are found in amphibolite only slightly granitized.

In the Maple ridge sill, where amphibolite forms the upper contact, the granite is coarsely porphyritic near the amphibolite and so remains for much of the width of the sill; but near the lower contact, which is against Grenville pyroxenic gneiss, it becomes finer-grained and much less coarsely porphyritic. Moreover, the narrow south end of the sill, where Grenville forms both contacts, is largely made up of fine-grained, nonporphyritic granite.

The narrow south end of the Hermon sill is also largely composed of fine-grained granite except in the immediate vicinity of the amphibolite beneath. The wider part of the sill is notably porphyritic, particularly at the north.

Although the narrow Moss ridge sill is chiefly of fine-grained granite, it also becomes coarsely porphyritic where it cuts into the amphibolite which forms part of its floor and lies between it and the Hermon sill. In fact, both the Moss ridge and the Battle hill sills lie so close to the Hermon that they doubtless connect directly with it not far underground (plate 9).

The ready attack of the granite on the amphibolite is no doubt due largely to the fact that the latter is an igneous rock. It is also quite gneissoid and hence more readily penetrated by the granite than many of the other rocks. The field evidence is also conclusive that much or all of the porphyritic granite is a mixed rock, having incorporated more or less amphibolitic material. The garnet-gneiss is also readily penetrated by granite with formation of injection gneiss, but does not seem to be actually digested by the granite as does the amphibolite, neither is the granite injecting it ever porphyritic. We are rather disposed to the view that the garnet-gneisses were injected by the Laurentian granite and were already in the condition of injection gneiss when the intrusion of porphyritic granite took place. In the Laurentian granites we have never seen any trace of porphyritic texture.

Porphyritic granites of this type show a close relationship to the green syenites over much of the Adirondack region, and are plainly differentiates of the same magma and of the same age. The syenite
often shows porphyritic phases at its margins and the dikes which run out from it are often coarsely porphyritic. The syenite also shows large capacity to assimilate material from igneous rocks with which it is in contact. The associated granite is quite generally porphyritic. It is not intended to imply that this porphyritic character is generally due to attack on amphibolite, for quite the contrary is true. For most of the region the relations shown are those which formed at a greater depth below the surface than is the case here. The relations on the Gouverneur quadrangle suggest that the granite sills are mere upward tongues from a large mass of syenite and granite below ground, which deeper erosion would disclose. Here the Grenville cover still persists and these small masses of granite which have worked their way up into it from below, found it easier to follow the rock structures already in existence, and hence came up along the dip, forming sills. Differentiation had taken place below ground, with granite above, then syenite and likely gabbro beneath. The granite tongues were injected upward from the upper part of the mass. Even in these small masses the granite was sufficiently fluid to produce ready attack on the related gabbro-amphibolite, although it had little effect on the sediments. In the former case it became porphyritic, in the latter it did not. Farther east much of the Grenville cover is gone, owing to greater erosion because of usual higher altitude, and the surface rocks of the present day there represent a deeper zone than those of the Gouverneur quadrangle. Doubtless conditions similar to those here formerly existed at the surface farther east, but erosion has carried the material away. Here conditions such as those now found at the surface farther east are still underground. The porphyritic texture in the syenite and granite seems to us in general to be due to assimilative attack of the syenite or granite upon its border rock. This is more particularly the case when the border rock is an igneous rock. When the intrusive is in large mass, however, it also attacks certain sediments and becomes porphyritic, as on the Saratoga quadrangle where the attack is upon Grenville mica-gneisses.

While mere inspection of the areal map is sufficient to suggest the sill structure of these granites, field data to definitely prove the matter are by no means lacking. The evidence in regard to the structure of the Reservoir Hill granite is particularly clear. This sill runs out to a narrow point at the north, but at the south has a surface breadth of a mile and plunges down under the limestone there in a broad, rounded front instead of running out to a point. There are a couple of bands of hard gneiss in the adjacent limestone
Plate 9

West face of Moss ridge from the west, 2 miles east of Richville, illustrating the sharp relief of the granite above the limestone flat of the foreground.

Plate 10

Grenville limestone overlying granite of Reservoir sill just southeast of Gouverneur village, granite on right, Grenville hog back on left, dipping away from the granite. The contact between the two is about midway of the depression where the thin edge of green syenite is shown.
of sufficient resistance to erosion so that a prominent hog-back ridge of Grenville runs all around the south end of the sill (figure 3 and plate 10). The Grenville strike follows the granite margin all the way around, dipping outwardly from it at an angle of about 30°. As we pass around the end to the southeast front of the sill and go north along it, the southeast dip of the limestone rapidly steepens, becomes vertical, and then shifts to northwest, in conformity with the dip of the sill and of the limestone above it on the west. The relations suggest that the intrusive first arose at the south end of the sill, thrusting its way up along the dip and crowding away the limestone at the south into parallelism with its margin, and that, from this beginning, it gradually pushed its way to the northeast, along the strike.

![Figure 3 Section of Grenville limestone hog-back ridge at south end of Reservoir Hill granite sill.](image)

At the southwest end of the sill, where the photograph shown in plate 10 was taken, the extreme upper edge of the granite, where it plunges down under the limestone, is of green color and greatly resembles the ordinary green syenite of the Adirondack region. It also contains both the peculiar green pyroxene and the bronzite which characterize the syenite, and allanite also. It is very quartzose, however, containing at least 15 per cent of that mineral. Evidence of contact action is shown by the development of tourmaline in the rock, but with that exception it is a quite characteristic sample of the acid phase of the syenite. There is very little of it, however. It is found only at the extreme south end of the sill, and has a thickness of but a few inches. It grades into the red granite within a thickness of a few feet, the intermediate rock being of brown color. This brown rock greatly resembles the ordinary weathered phase of the syenite elsewhere and no fresh material could be obtained from it. There is a small quantity of some wholly altered femic mineral in it which may have been pyroxene. This explanation is rendered quite probable by the fact that some hornblende is present in comparatively
unaltered condition so that it is quite unlikely that the wholly altered mineral is hornblende. The brown rock grows steadily more quartzose as the red granite is approached, the granite holding approximately 25 per cent of that mineral as compared with 15 per cent of the green syenite.

On seeing these relations in the field our first thought was that here was a narrow chilled border of the granite sill. Unmistakable green syenite was found only at the extreme south end. Elsewhere along the southeast face of the sill, which is its bottom, a small thickness of altered brown rock is found, but no certain syenite. At the top of the sill exposures of the contact are rare, but in one locality, where blasting had been done along the roadside, the upper few inches of the intrusive were of gray color and contained pyroxene. No rock at all suggesting syenite was seen in the narrow northern half of the sill. All seen there is of monotonous red granite, and at the south all is red granite except for the thin selvage of possible syenitic material. In other words, there is no sign of differentiation within the sill, the bottom being of the same rock as the top. Without differentiation there could be no such thing as a chilled border, within the ordinary use of the term. No sign of differentiation or of a chilled border has been noted in any of the other sills, even in the great Hermon sill, although similar thin selvages of syenite may be present in them and have escaped notice because of lack of suitable exposures.

These granite sills today have steep dips, in conformity with those of the folded Grenville beds within which they lie. Did the Grenville folding precede the granite intrusion, or come later?

In an ordinary, flat-lying sill, in rocks not much disturbed, differentiation may take place in the intrusive before solidification, giving rise to less siliceous rock below and more siliceous above, with frequently a chilled border representing the quickly cooled, undifferentiated magma as first intruded. Where the beds were steeply tilted at the time of the intrusion, however, even if some differentiation took place in the liquid and less siliceous material collected downward, the contact between this and the more siliceous material above would not be parallel to the steeply inclined base of the sill but parallel to the horizon, and it would be practically impossible to tell in most cases, from any surface exposures, whether any differentiation had taken place or not. In this particular instance the thin selvage of syenite at the south end of the sill does distinctly suggest a chilled border, since it grades into the granite.
This close relation between syenite and granite here disclosed, is quite in line with the relations shown between the two rocks in many other localities in northern New York. The two rocks are closely related, are differentiated from a common magma, and are of substantially the same age, as has been many times demonstrated. But the relations shown at the Reservoir sill do seem to have a bearing on the question of the date of the folding of the Grenville rocks, as will be later considered under the caption of structural geology.

Diabase Dikes

Throughout northern New York the youngest rocks of Precambrian age occur solely in dike form. The usual rock of these dikes is a dense, black diabase, popularly known as trap. In a small area in Clinton county, centering around Rand hill on the Mooers quadrangle, the trap dikes are accompanied by another group of more siliceous nature, usually of red color and of approximately the same age. Elsewhere only the trap dikes are found. These are very abundant in the eastern, and especially in the northeastern part of the region, and are also conspicuous in the Thousand Islands region, but between the two districts they are much rarer. Only two of these dikes have been noted within the Gouverneur quadrangle, one cutting the Grenville limestone in one of the quarries south of the village of Gouverneur, and the other in the extreme northern part of the quadrangle, 1 mile north of Osborn lake, in the tongue of higher land lying between the swamps of the two branches of Beaver creek. This dike cuts Grenville mica-gneiss. It is well shown in a rock cut by the roadside, and is unusual in that a branch of it cuts irregularly into the enclosing gneiss, instead of having the customary, sharply-defined dike form, as shown in figure 4. It is a quite typical olivine diabase, labradorite,
violet-colored pyroxene, much olivine all gone to serpentine, magnetite with biotite corrosion rims, and good ophitic structure.

No doubt there are other representatives of these dikes within the quadrangle in addition to the two seen, but it is certain that they are very infrequent, and cut practically no figure in the general geology.

Potsdam Sandstone

There is no evidence that any Precambrian sedimentary formations, aside from the Grenville series, were ever deposited in northern New York. The evidence is clear that long-continued erosion of the region took place in later Precambrian time, with removal of much material and reduction of the land surface to comparative evenness. The surface thus formed was even, however, only in the large sense; in minor fashion it was quite uneven, the resistant granites, garnet-gneisses, quartzites etc., standing in relief from 100 to 200 feet above the lower grounds occupied by the limestones and weak mica-gneisses and rusty gneisses. On this uneven surface Potsdam deposition began, to be followed in its turn by other early Paleozoic formations.

Since these formations were laid down, erosion has removed all trace of them from the surface of the Gouverneur quadrangle, except that numerous, yet generally tiny patches of Potsdam sandstone still remain. Some of the later formations are still to be found at the surface, overlying the Potsdam, on the Ogdensburg quadrangle next north, and have been described in the report on that quadrangle. Some three dozen of these remnantal patches are shown on the areal map of the Gouverneur quadrangle, and there are at least twice as many more which are altogether too small to map on this scale. The largest mass present, located 1 mile north of Halls Corners, is less than a square mile in area.

These residuals occupy what were the very lowest spots of the old surface of deposit, spots where the sand deposit first began and where it accumulated to greatest depth. Since the Grenville limestone is the least resistant Precambrian rock of the quadrangle, being subject not only to mechanical erosion but also to chemical, owing to its slow solubility in rain water, it follows that practically all these residuals rest on Grenville limestone. They are most abundant in the great limestone belt which the Oswegatchie river follows from Oxbow to below Rock Island bridge, but they are found on limestone throughout the quadrangle.
"Dike" of Potsdam sandstone in Gouverneur limestone at the "four corners" just south of Rock Island bridge. This is a sand-filled solution fissure of the old Precambrian surface, now in relief because it does not yield to modern rain attack as the adjacent limestone does. This is one example of the many in the vicinity. Potsdam sandstone in place on top of the limestone occurs near by.
Prior to the beginning of sand deposition chemical attack of rain water on the limestone had not only lowered its surface but had also widened the joint cracks which reach down below ground from the limestone surface, precisely the same process now going on where bared surfaces of the Paleozoic limestones are exposed to weather attack, as they are in numerous places in the Thousand Islands and Ogdensburg districts. Into these widened joints sand sifted when sand deposition began, and these sand-filled cracks in the limestone, the sand now appearing as hard sandstone, may be seen in several places on the Gouverneur quadrangle, most notably at the Potsdam patches near Peabody bridge and at the patch just south of Rock Island bridge. The sandstone filling the cracks is today more resistant to erosion than the enclosing limestone, so that on bared limestone surfaces the red sandstone stands out in relief, and the resemblance is very strong to the appearance of dikes cutting the limestone (plate II).

In some of the larger sandstone remnants a thickness of from 10 to 15 feet of sandstone is shown, but in most of them the thickness is much less. The rock varies much in the different exposures, and within the same exposure. It is sometimes red, sometimes white and sometimes red and white banded. It is usually very thoroughly cemented and vitreous, but locally the base, where resting on the limestone, is very calcareous and weakly resists erosion. Some coarse conglomerate occurs. Where this is basal the pebbles are apt to be very angular and to show little attrition; in fact, these basal conglomerates are very local, lie in hollows in the limestone surface, and seem surely to be so-called residual conglomerates. The angular pebbles are either of Grenville quartzite or hard gneiss, or else of vitreous sandstone. Where conglomerate occurs above the base the pebbles are generally much more rounded.

From Potsdam west to Clayton the Potsdam sandstone formation is rather thin, and in places where the Precambrian floor was highest on the granites and garnet-gneisses for example, it may entirely fail, and the Theresa formation lie on the Precambrian. East of Potsdam the formation rapidly thickens by the successive addition of beds at the base. In other words, the thin formation present from Potsdam to Clayton represents only the summit of the formation as it occurs more to the eastward. This upper portion consists largely of somewhat calcareous, not extra-resistant sandstone, of brown or white color, carries marine fossils sparingly and seems an unquestionable marine formation.
The sandstone found in these residual patches on the Gouverneur quadrangle differs from the above in color and in being very vitreous and hard, and noncalcareous except locally when in immediate contact with limestone. Angular blocks of hard red sandstone are also found as pebbles in the basal conglomerates. The phenomena are quite as they are in the Thousand Islands region and, as shown in the report on that district, suggest that this lower, hard sandstone is materially older than the ordinary Potsdam of the region, although it is not thought to be older than the basal portion of the Potsdam sandstone of Clinton county. It also seems to be a nonmarine accumulation. The evidence is not yet clear, however, as to the precise significance to be attached to the observed phenomena. It is quite certain that the deposit of the sand in these hollows of the old surface was not immediately followed by the sands which form the general Potsdam of the region, but that a time interval lay between. Whether this was a long interval, or merely a comparatively short one, is at present not known. The writer is of the opinion that the older sand here is the approximate equivalent of the basal portion of the formation as it appears in Clinton county, and that the other in like manner is equivalent to the summit, and that there is nothing here equivalent to the middle division of the formation in Clinton county. It is quite possible, however, that there is a break between the lower and middle divisions of the formation there, and the whole formation is very thick, at least from 1290 to 1500 feet. There is at hand today very little direct evidence in substantiation of the above opinion. The general Potsdam of this northwestern area is very thin and is the unquestionable equivalent of the extreme summit of the formation in Clinton county. The precise age of the basal sands of these hollows is an entirely open question.

STRUCTURAL GEOLOGY

Strike and Dip

The general strike of the Grenville rocks across the Gouverneur quadrangle is to the northeast and the prevalent dip is to the northwest. In these two respects the structure is in close accord with that of all the surrounding quadrangles of the immediate region. There is a considerable amount of swerving in the strike from place to place. Thus along the southern margin of the quadrangle nearly north strike prevails, while 2 miles to the north it has swerved to a
direction more nearly east. The areal map plainly shows the general nature of the strike within the quadrangle, and its somewhat curving character.

In certain places strike directions which depart widely from this general one are found, but in the greater number of these the changes are local and rapid, the strike swinging round through an arc of 90° or more, and the explanation is to be found in the folded character of the rocks, as will be immediately shown.

The dips vary much in amount, but are seldom less than 25°, and over the greater part of the quadrangle average at least 45°, while often they are much steeper than that figure. Departures from the usual northwesterly direction are exceptional, are local, and again, in the great majority of cases can be shown to be due to the fact that the rocks are closely folded and that the folds often show sharp pitches, sometimes to the northeast, sometimes to the southwest. A study of the areal map would distinctly suggest the close folding of the rocks, even were direct evidence of this folding not obtainable in ample measure in the field.

**Foliation**

By foliation is meant the particular type of cleavage which is produced in rocks which are subjected to great pressure under such conditions that they crystallize, or recrystallize if they were already crystalline. In a mass of rock compressed in this fashion, the tendency is to diminish its extent in the direction of the pressure, and to increase it in the plane at right angles to the pressure. When a rock recrystallizes under such pressures, usually certain scaly minerals, such as the micas, or certain fibrous minerals, such as the amphiboles, are formed. The scales or fibres so produced will arrange themselves in accordance with the pressure direction: the flat sides of the scales will all be aligned in the plane at right angles to the pressure direction and the long axes of the fibres will also lie in this plane. Such an arrangement of these minerals results in giving to the rock a much more ready capacity to split in the direction of the plane at right angles to the pressure direction, than in any other direction, this capacity being a direct result of the peculiar mineral arrangement.

Obviously the perfection attained by such a cleavage will depend upon the production of either scaly or fibrous minerals in quantity in the rock. With diminution in their amount the cleavage becomes progressively less good. Thus the different schists and gneisses of
the Grenville series show great variation in the perfection of their foliation cleavage, according to their mineralogic make-up. The pure limestones, and much of the granite also, lack such minerals, and show little or no foliation. Gneisses and schists are foliated rocks, the latter in general with more perfect foliation than the former.

Wherever known the Grenville rocks are completely recrystallized and strongly foliated. A certain combination of pressure and temperature conditions is requisite in order to produce such a complete alteration in a widespread and very thick rock series. Under very great pressure thorough recrystallization may be brought about with only moderate temperatures; with less pressures higher temperature is necessary in order to produce an equivalent effect. Extreme recrystallization such as the Grenville series has experienced is probably produced only under fairly high temperatures, irrespective of the pressure.

In districts where the rocks have been folded, as a result of strong, lateral compression, some recrystallization and development of foliation often takes place. Where the folded terrane becomes invaded by considerable masses of igneous rocks, very pronounced foliation may be induced. Such foliation will have steep inclination because it will form in the planes at right angles to the direction of lateral compression. It apparently can not everywhere lie parallel to the bedding planes of the sedimentary rocks, but must make an angle with them, especially along the crests and troughs of the folds.

The foliation of the Grenville rocks seems everywhere parallel to the bedding. Neither in New York, nor in Ontario or Quebec has any instance of discordance between the two ever been reported as far as I am aware. In the Gouverneur district this parallelism between the two is everywhere manifest, both possessing the same general northeast strike and northwest dip. That the rocks are strongly and closely folded will be later shown; nevertheless this parallelism persists throughout. It is difficult to see how this could be true had the foliation arisen as a result of the lateral pressures which caused the folding. Miller has used this parallelism as an argument to support his contention that the Grenville rocks are in general not greatly folded. To those who believe in their general folded condition, the conclusion seems irresistible that the foliation must have preceded the folding and that the rocks were already recrystallized and foliated at the time when they were folded,
instead of having had the foliation produced as a result of the folding. Rocks already foliated, and with foliation and bedding parallel, could conceivably have become folded without the destruction of this parallelism.

Many years ago Van Hise directed attention to this concordance of foliation and bedding in the Adirondack Grenville, and was, as far as I know, the first to suggest that this might be due to mere downward weight of overlying rock, unaccompanied by side pressure. He says:

In the formation of schistosity parallel to bedding, which occurs in part of the district, vertical shortening and consequently horizontal elongation below the level of no lateral stress, may have begun the process. When the rocks were subsequently folded the different degrees of strength of differently indurated beds evidently controlled the direction of differential movement, and the production of cleavage parallel to bedding was thus assisted.¹

Recently W. J. Miller has discussed "Foliation in the Precambrian of New York," and R. A. Daly has referred to the region as an illustration of "load metamorphism" as incidental to an elaborate discussion of the classification of metamorphism.² Miller argues that "We are thus forced to the only alternative conclusion, namely, that the Grenville foliation was developed during the crystallization of essentially horizontal strata under heavy load of overlying material."³ The fact that he bases a part of his argument on the contention that the Adirondack Grenville is essentially today in an unfolded condition, which does not correspond with our belief, does not vitiate the remainder.

Daly urges that the mere fact that foliation and bedding are parallel, in a terrane of recrystallized sediments, is prima facie evidence that the recrystallization took place under conditions of simple loading, the mere downward weight of the overlying sediments, and adduces the Adirondack region as one in which the process is illustrated.⁴ He explicitly recognizes that in regions occupied by the most ancient Precambrian rocks the sediments rest on, and are much invaded by igneous masses, with the production of a considerable amount of contact metamorphism and a considerable bulk of injection gneisses, and that these effects are to be added to those of the load metamorphism.

² W. J. Miller Jour. Geol., v. 24, p. 587-619.
The writer quite agrees with this view of the origin of the foliation cleavage of the Grenville rocks. It should be noted, however, that the whole subject is involved and difficult, that lack of agreement prevails in regard to it, and that precise knowledge is lacking. The above view seems to us that most promising and plausible explanation of the correspondence between bedding and foliation, such as we have here, which has yet been offered. If it be true, or a close approximation to the truth, certain important consequences follow.

In the first place, it is necessary to assume that, at this very early period in the earth's history, its inner heat was much more prominently effective comparatively near the surface, than is the case today, and as has been the case all through the later part of geologic time; the rate of rise of temperature in passing beneath the surface must have been considerably more rapid than at present. This assumption is necessary because elsewhere Paleozoic and later rocks have been buried under a thickness of from 25,000 to 30,000 feet of superimposed rock material without undergoing any recrystallization whatever, or else in only trifling amount. There is no evidence that the Grenville rocks which today appear at the surface were ever buried any deeper than the above amounts; quite possibly the burial was not as deep. Daly explicitly admits the necessity for this assumption.

In the second place, since the Grenville rocks have been closely folded, under conditions of high lateral compression, if not everywhere, at least over a large part of the territory in which they are found, it follows that they must have been foliated before they were folded. Having already completely recrystallized under pressure, they either did not again recrystallize when they were folded under lateral compression, or such recrystallization as did then take place was controlled in direction by the already-existing foliation, and followed that, instead of conforming everywhere to the plane at right angles to the direction of compression.

The granite-gneisses of the Laurentian are also foliated, not strongly so because of their composition and hence small content of scaly and fibrous mineral particles, but as thoroughly as their mineralogic make-up allows. Their foliation is everywhere parallel to that of the bordering Grenville, and they are much more prominently and uniformly foliated than are the members of the later group of igneous rocks. The gabbros, now amphibolites, which preceded them, are much better foliated, because of their abundant hornblende and lesser, but still considerable, mica content. These gabbros are
strongly infolded with the Grenville rocks and their foliation follows the curves of the folds. It seems likely, therefore, that their foliation also was produced under conditions of mere downward weighting instead of under lateral pressure.

It is quite possible that the intrusion of the Laurentian granites was responsible for a certain amount of the folding shown by the Grenville rocks; and it is quite probable that the granite intrusions occurred while the side pressures were in operation and the folding was going on. It is also in the highest degree probable that folding continued long after the granite injections had ceased.

**Folds**

Where rocks are subjected to pressure of sufficient amount and duration from the side, they shorten their extent in the direction of the pressure by wrinkling or folding, such folds trending in the direction at right angles to the pressure. In general rocks can not fold at or very near the earth's surface since there they are too rigid and brittle, so that they fracture rather than fold. Deeper down, under the load of a sufficient weight of overlying rock, they are less rigid and bend rather than break. The folding may be only gentle, but if sufficiently great pressure endures for a long enough time, the folds become increasingly more pinched and more tipped. Excessive pressures may so pinch them that the two limbs become nearly or quite parallel, the dip in the same direction and of substantially of the same amount on the two sides. Folding of this type has usually been styled "isoclinal" folding because of the similarity of dip on the opposite limbs. Where a series of rocks has been tightly pinched up into a succession of such isoclinal folds, and subsequently the folds have become truncated by long-continued erosion, the surface exposures will consist of successive rock beds with the same dip and strike. In recrystallized, nonfossiliferous rocks, such as those of the Grenville series, in which few or none of the individual beds present characters so definite as to enable the certain identification of the bed wherever it may occur, it becomes an exceedingly difficult matter to demonstrate that the rocks are actually folded. A series of unfolded rocks which had been tilted as a whole and then truncated by erosion would consist of successive rock beds with the same dip and strike, and would thus present a very similar appearance to the other (figures 5–8).
Figure 5 Diagram of gently folded beds which have been truncated by erosion, the upper dotted portion having been worn away; showing the broadly open character of the folds and the dips in opposite directions of the two lines.

Figure 6 Diagram of more closely pinched folds, also truncated by erosion; folds somewhat tipped giving much steeper dips on one limb of a fold than on the other.

Figure 7 Diagram of very closely pinched folds, strongly tipped, and truncated by erosion; dips are all in the same direction and similar in amount; typical isoclinal folding.

Figure 8 Diagram of tipped, but unfolded beds, truncated by erosion; dip of substantially the same amount and direction as in the case of the isoclinal folds of the previous diagram. In that diagram all the dotted beds represent different portions of a single folded bed, while in this they represent so many separate beds. The thickness of beds represented on the isoclinally folded series is comparatively small, while in this diagram it is very large. If the two structures are confused very erroneous ideas in respect to the rock thickness may result.
Most of the men who have worked in the field on the Adirondack Precambrian have come to the conclusion that the Grenville series is tightly folded, in isoclinal fashion. Thus Kemp, Smyth, Newland and Cushing have repeatedly stated this to be their view. More recently, however, W. J. Miller has urged that over much of the region these rocks are not strongly folded, and that such folding of this character as does exist is local only, instead of being regional, and is due to the local effects of igneous intrusions instead of to regional lateral compression.\footnote{Jour. Geol., v. 24, p. 588-93.} Daly also has expressed the view that in many parts of Canada and of the Adirondacks the Grenville is not greatly folded, but lies rather flat and comparatively undisturbed. Miller has suggested a contrast between the Adirondack region and the Thousand Islands region in this respect, granting that the Grenville is more folded in the latter area than he thinks it is in the former.

Within the Gouverneur quadrangle the evidence that the Grenville beds are closely folded is exceptionally clear. The sediments are much less involved with igneous rocks than in most of northern New York, and occur in long and wide belts, with abundant exposures. These structures will be described, and their bearing on the general question then set forth.

Although there are many bodies of igneous rock within the quadrangle they are generally of small size, and many of them are sills instead of being cross-cutting bodies which do not at all interfere with or disguise the sedimentary structures. Larger bodies do interfere to the extent of causing some curvature in the strike of the sedimentary beds, but that is all. Across the northern portion of the quadrangle is a nearly uninterrupted Grenville section, broken only by the sills of amphibolite and granite which form Maple ridge.

As the areal mapping of the quadrangle proceeded, locality after locality was found where the general northeast strike, and northwest dip of about 40°, was interrupted by a sharp bend in which the strike became northwest and the dip northeast. Such a swing takes place at the Cole mine, for example, in the pyritic quartzite and the underlying limestone. These small folds always showed strong pitch, and seemed most naturally explainable as small, secondary, pitching folds on the limbs of larger folds. Such appear on the map in but few places, partly because many of them were too small to map on this scale, partly because they occurred within what are mapped as single formations, the contrasted beds being
too thin for separate mapping. There are many such small folds, for example, within the belts mapped as impure limestones.

Another frequent observation was the disappearance of a given bed, or formation, along the strike. Here also the impression invariably given was that the disappearance was due to the carriage of the bed or formation below ground because of a pitching fold of which it was the central member. In places it was possible to actually demonstrate this, and to follow the bordering bed as it folded around the end of the disappearing one.

On the western border of the quadrangle several examples of unmistakable pitching folds were seen. A small syncline in hard gneiss, with limestone above and below, with southwest pitch, may be seen at the west margin of the sheet, just north of Natural Dam. A similar one occurs 2 miles farther north, and to the prolongation of this belt on the Hammond sheet Buddington has recently referred in the following words:— "a narrow belt, here called the Laidlaw belt, in the town of Antwerp, running from Halls Corners to Oxbow — this is simply the northwest limb of an isoclinal syncline of gneiss of which the Keene-Antwerp belt is the southeastern limb, the two limbs connecting with each other along the strike at Halls Corners."1 It is the apex of this syncline which lies within the Gouverneur quadrangle, to which reference is here made; and it is to be observed that Buddington's interpretation of the structure is precisely the same as that here set forth, although a result of independent and of subsequent work. There are other excellent examples of the same sort of thing on the Hammond sheet.

Much the clearest evidence of larger scale Grenville structures was obtained in the southeast portion of the quadrangle, and more particularly along the contact line between limestone and garnet-gneiss to the south of Edwards. Much of this territory Newland and Cushing visited together. We were quite in harmony in regard to its testimony, and Newland has since published a section across the belt, in illustration of its structure.2

A great belt of garnet-gneiss with a width of 3 miles or more comes in from the south on the southeast corner of the Gouverneur quadrangle. To the north this great belt pitches down and disappears under the limestones of the Edwards belt. It not only pitches down as a whole, but its western margin is characterized by infolded tongues of limestone and garnet-gneiss, which are minor folds on the.

1 N. Y. State Defense Council, Bul. 1, p. 3-4.
west limb of the large one, and show the same pitch. The strike is somewhat east of north and the dips are to the west and fairly uniform, some $35^\circ$ to $45^\circ$. A very prominent narrow tongue of garnet-gneiss is shown on the Gouverneur map, its final termination being just over the border on the Russell quadrangle, with a great infolded tongue of pure limestone separating it from the main mass of the garnet-gneiss, the termination of which also lies on the next quadrangle. Outcrops are numerous, and the field evidence seems clear that the garnet-gneiss forms a great anticline, with many subsidiary anticlines on its flank, and that the limestone overlies it. It is the downward pitch of these subsidiary anticlines to the north, and their disappearance one by one beneath the limestone, that is responsible for the peculiar contact line between the two formations, and for the increase in breadth of the limestone belt at the expense of the garnet-gneiss in going north. The most decisive evidence of the folding and of its nature was obtained where the limestone wraps around the ends of these disappearing tongues. In figure 9 a sketch of a portion of the contact between these two formations is shown, on which appear the section lines of the sections shown in figure 10.

These sections show clearly the nature of the evidence. In the section $A-A$, made near the northerly point of the garnet-gneiss, the limestone west of the gneiss dipped to the west while that east of it dipped to the east, and their strike was somewhat divergent; in fact,
as the limestone was followed around the front of the garnet-gneiss tongue its strike steadily swerved in parallelism with the contact.

As the east margin of the gneiss was followed to the south from the section line $A-A$, this easterly dip rapidly steepened as in section $B-B$, reached and passed the vertical as in $C-C$, and thereafter became a west dip which steadily became less steep, till it reached substantial accordance with the dip on the west side. Section $D-D$ shows a close approximation to this condition, and also

![Figure 10 Sections A, B, C, and D across the end of the pitching fold of garnet-gneiss.](image)

represents a section across an isoclinal fold. The sections simply represent stages in a continuous process. Folding is suggested by such a section as $D-D$, although by itself it would be impossible to say whether the structure was anticlinal or synclinal; but when combined with the other sections the evidence becomes conclusive that we are dealing with a closely pinched anticline which pitches north.
These sections are across one of the subsidiary folds on the west limb of the main fold. Sections across the downward pitching snout of the main fold, on the Russell sheet, however, are of precisely the same type. It follows that the limestone of the Edwards belt forms a syncline, and that the tongue of limestone running southwest into the garnet-gneiss, the one shown in the sketch (figure 11), is a minor syncline on the flank of the anticline of gneiss. Newland has published a section to express his conviction that the Edwards limestone belt has synclinal structure; and our section E—E (figure 11) which runs across two of the subsidiary garnet-gneiss tongues and shows part of the main anticline at the extreme east, gives our interpretation of the general structure, on what seems to us conclusive evidence.

Figure 11 Section E—E, showing two infolded minor synclines of limestone, between anticlines of garnet-gneiss, on the flank of the great fold of garnet-gneiss which is partially represented at the right.

Within the Edwards limestone belt, 1 mile southeast of Talcville (see areal map), a considerable knob of rusty gneiss is domed up. The structure is clearly that of an anticlinal dome, arched up within the limestone as a subsidiary small anticline in the bottom of the limestone syncline, and with a very rapid pitch below ground at both ends. Buddington also considers, from independent work, that the structure here is anticlinal. The general dip of the schist and of the surrounding limestone is to the northwest except at the ends of the dome, where the schist pitches below ground. At these points the limestone wraps round the ends of the schist and variations in dip similar to those which have just been described occur.

Talcville Cuts

The Edwards branch of the New York Central and Hudson River Railroad runs through a narrow belt of hard gneisses, for a mile and a half just east of Talcville, a belt which lies within the limestone series and is closely bordered by the talc and zinc deposits. The surface of the belt is moderately rugged and the railroad has made frequent rock cuts. Two of these cuts are squarely across the ends of minor folds, with strong northerly pitch, which show excellently in section. A sketch of the relations shown in one of them appears in figure 13, and the other is very similar. The section is near the nose of the fold so that, while the dip on the west limb is normal, that on the east has not yet swung around to parallelism with it, and the conditions represented are similar to those shown in section $A-A$ of figure 10. The rock face in the cut is 10 feet high and many yards long, so that a fold of moderate size is here shown, instead of a mere plication.

Plications

Many of the Grenville beds are intricately contorted and plicated. Miller states it as his experience that such plications are largely confined to the limestone beds.\(^1\) Our own experience is so dia-

Contorted color-banded limestone of Grenville series by the roadside 1 mile northwest of Pine Hill, Hammond quadrangle.
metrically the opposite that a special point must be made of it. It seems to us that the limestones show such structures least well of any of the Grenville beds, and that the quartzites, especially the thin-bedded members of the group, show them best. An occasional banded limestone, such as that shown in plate 12, does show them well, but that particular picture was taken because of its exceptional nature. Such thoroughly and beautifully plicated limestones as those of the Hastings series in Ontario consist of rapid alternations of limestone and of para-gneiss, and not of pure limestone; and such impure limestones do often show plications excellently.

The evidence seems quite conclusive that the Grenville rocks, across the entire width of the Alexandria Bay, Hammond, Gouverneur and Russell quadrangles, lie in a series of closely pinched, isoclinal folds. On the Canton quadrangle, just north of Hermon, Martin reports the Grenville as closely folded, with some folds of unusual type. On the Lake Bonaparte quadrangle, next south of

Figure 13 Section in railroad cut not far east of Talcville, across the nose of a pitching isoclinal fold in hard gneisses.

Gouverneur, Buddington reports similar folding. These are the quadrangles in northern New York in which the Grenville series is best developed, most widespread, and least cut away by igneous rocks, therefore the quadrangles in which the problem of Grenville structures can be most successfully attacked. It is to be noted that the observed close folding obtains across a width of four quadrangles; that a width of only six additional quadrangles intervenes between the Russell quadrangle and the Paleozoic rocks along the shores of Lake Champlain; in other words, that 40 per cent of the width of the New York Precambrian is comprised in these four quadrangles. Is not then the query justified: Where does the Thousand Islands region end and the Adirondack region begin? As a matter of fact, any separation between the two

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regions is purely fanciful. The western district has been less deeply eroded than the east, and hence shows more Grenville, less igneous rock, and a slightly less degree of metamorphism; but there is a gradual passage from one district to the other in all these respects; they belong together in all aspects except the topographical; and no man can draw a satisfactory geologic boundary between the two.

The general problem of the structure of the Grenville rocks can be stated something after this fashion: Here is a great series of very old, thoroughly recrystallized sediments which, at least in New York, rests always on a floor of various igneous rocks, all of which are demonstrably younger than it is, and which have invaded it from below. The present surface, in the eastern part of the region, consists much more largely of the igneous rocks than of the Grenville, and the latter occurs in separate masses, surrounded and enclosed by the intrusives. There is more Grenville remaining in the western half of the region, and in the western third it equals or exceeds the intrusives in surface extent, and the Grenville areas are more or less well connected with one another.

The general structure of the separate areas suggests usually a great monocline. The dips vary much in amount and are sometimes quite flat, although usually of $30^\circ$ or more; and over much of the district equal or exceed $45^\circ$. If the structure be actually monoclinal then the series has an enormous, an unheard of thickness. While it is unquestionably a very thick group of rocks, such thicknesses as 94,400 feet, obtained by direct measurement on a supposed monocline under unusually favorable conditions, thicknesses several fold in excess of those of any other known sedimentary group, and thicknesses obtained by the measurement of what is confessedly only a part of the series, neither base nor summit showing and certain well-known rock types which belong to the series being absent in the section, can not but throw doubt on the verity of the suggested structure.\(^1\)

Eroded isoclinal folds closely imitate monoclines, and can not successfully be discriminated from them in cases in which it is difficult, or impossible, to recognize individual beds from place to place. If we regard the Grenville series as isoclinaly folded, we

\(^1\) In their account of the measurement of this section Adams and Barlow state that it is impossible to determine whether repetition by isoclinal folding has taken place or not, as there is no horizon sufficiently well marked to permit of its being recognized in a repeated series. They also give $45^\circ$ as the average dip, and state that, since folding has nowhere brought up the basement on which the series was deposited, it must be very thick, even if isoclinally folded.
are relieved of the necessity of assuming for it such prodigious thicknesses.

Miller has described several instances in which masses of Grenville lie upon syenite or granite after the manner of a roof, in which it seems to him certain that the Grenville beds have been domed over the uprising magma, and that their present dips are due to this doming. We find no fault with this interpretation; it seems to us obvious that the great igneous masses must have often produced effects in the overlying Grenville such as he describes. The question is do these effects show plainly that the prior condition of the Grenville was an unfolded one? That does not seem to be a necessary conclusion.

It seems to us demonstrated that the Grenville rocks, in the western 40 per cent of the Precambrian of northern New York, are pinched into tight folds. It seems probable that they were first foliated under load metamorphism, and subsequently folded. It seems to us probable also that much of the folding took place during and after the intrusion of the Laurentian granite-gneisses, but before the date of the later intrusions. These latter, of the anorthosite-syenite-granite-gabbro series, lack the predominance in this northwestern region that they have in the eastern Adirondacks, and occur mostly as relatively narrow sills, whose position was controlled by the Grenville structures already in existence. The contrast between the two districts is thought to be chiefly due to the greater erosion which has affected the eastern one; conditions such as prevail at the surface in the east today are thought to occur well below ground to the west; the intrusive sills are upshoots and offshoots from the greater mass of the intrusives beneath. At a depth of a mile or two beneath the surface of the Gouverneur quadrangle, it is inferred that there would be a vastly greater extent of the intrusives and much less Grenville, and the Grenville would occur in separate patches amid the intrusives, quite as it does at the surface in the east today. The zone corresponding to the present surface in the west was formerly present in the east also, but long since disappeared through the agency of erosion.

If an isoclinal folded series, such as we conceive much of the Grenville to be, were invaded from beneath by great, upwelling masses of intrusive magma, the deeper portions of the sediments would be much more affected than would those more remote. The upper surface of the intrusions would be very irregular, great

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wedges of Grenville would remain in the depressions between the higher protrusions of the magma, large masses of Grenville would break away and sink somewhat in the molten mass beneath, and these masses would tend to be variously tilted. Some of them would have their initial dips steepened in the process, others would have them lessened. Masses of the latter type might well appear to consist of unfolded sediments with very gentle dips.

We must either admit that the Grenville series has a stupendous thickness, many times greater than that of any other known sedimentary rock group, or else conclude that much of it is closely folded. The only possible alternative is to hold that what appears to be bedding is not true bedding, and hence gives a deceptive idea of the true thickness. We do not know of a vestige of evidence in favor of this conception. Since the condition of close folding is demonstrable over a considerable portion of northern New York it seems to us reasonable to infer that such a condition prevails over much of it. The gentle dips and the doming of Grenville masses on the intrusives which occur locally in the eastern region may be due to the tilting of certain blocks into more nearly horizontal position, and to the tendency of the intrusions to utilize bedding and foliation planes as their points of easiest attack.

It is not contended that the Grenville rocks are everywhere closely folded, but it is urged that such folding does prevail over great areas. Agreement with Miller in his contention that the Grenville on the west is more strongly folded than on the east, is not difficult; but from that it by no means follows that his view that, in the latter region, a generally unfolded condition exists is the true one. It is in the highest degree probable that the degree of Grenville folding varies from district to district; that close folding prevails in some belts, gentler folding in others, and little or none in yet others. It is a part of the work of the future to specifically separate and delimit the areas of each type. Today we possess merely enough knowledge to indicate that the three types of structure do exist, and that it is unsafe to generalize upon the structure of the whole series everywhere, from the structures found to obtain in a limited region. This applies equally to New York and to Canada. It is true, however, that close folding often prevails, and that in districts where the dip is steep and where the assumption of an unfolded condition necessitates the belief in a prodigious thickness for the series it is highly probable that the rocks are really folded.

Present opinion in Canada upon the question may perhaps be sufficiently indicated by quotations from two letters received, one
from Adams and Bancroft, the other from W. G. Miller and Knight. Adams writes concerning the view of Bancroft and himself:

We agree that all that can be said is that in the explorations which have gone forward in the Grenville series during the period of approximately 60 years which has elapsed since the publication of the Geology of Canada in 1863, it has been ascertained that the whole Grenville is not everywhere sharply folded as Logan represented it in the original Grenville area, but that there are great tracts of the country over which the strata of the Grenville series are either flat or lie in very gentle undulations. Elsewhere, of course, they are sharply folded, but the question of the relative areas of the sharply folded and the flat portions of the series is a matter concerning which no definite statement can be made at present.¹

Miller and Knight say:

Although we studied in a general way the question of folding throughout the Grenville of southeastern Ontario, we nevertheless have not attempted to determine whether close folds predominate, or whether gentle folds are more common. But at the same time it may be said that, as a rule, the Grenville beds now occur in vertical or steeply inclined attitudes. In our work we studied with special care the question of folding in but two small areas, namely the Madoc area and the Queensboro pyrite area. In both areas there are examples of very close folding and also of gentle folding.²

Miller states in addition:

I have seen very little Grenville that is not much disturbed. A pseudo-bedding has sometimes been developed which is confusing and might lead one to infer that rocks had not been much disturbed. The original structure in the limestones has in some cases been entirely destroyed.

In comment it may be pointed out that the district in southeastern Ontario, in which Miller and Knight report usual steep dips, and much folding, is closely adjacent to the western Adirondacks, in which our results are quite similar; that in the more easterly districts which are included in the Adams and Bancroft statement large sized tracts of unfolded Grenville occur; and that W. J. Miller contends that the general Grenville in the eastern Adirondacks is unfolded. There does seem ground, then, for concluding that along one great belt, comprising the western Adirondacks and southeastern Ontario, the general Grenville is much folded, and

¹ Letter of March 8, 1918.
² Letter of March 4, 1918.
that in a more easterly belt considerable unfolded Grenville occurs. It is quite probable that some of the Grenville of the eastern Adirondacks is comparatively unfolded, but when its fragmentary character is considered, together with the fact that many of the fragments seem to have been completely broken away and completely inclosed in the intrusives, and have probably been variously tilted, it seems to us in the highest degree unsafe to contend that an unfolded condition is the prevailing one.

Granite Sills

That the porphyritic granite of the quadrangle occurs in sills has already been pointed out. Certain features of the occurrences, however, lead to the belief that the Grenville series was already sharply folded, was in substantially its present attitude, at the time when the granite was injected. In other words, the folding is older than the granite is. The granite sills were not tipped as a result of regional folding after they were intruded, but the granite was injected into beds already folded and with steep dips, and worked its way upward following the dips.

The Grenville inclusions in the sills, particularly the large inclusions in the Hermon sill, give important testimony. Take the Tanner creek inclusion for example, the largest and most significant of all. This inclusion is nearly 5 miles in length, and in width between \( \frac{1}{4} \) and \( \frac{1}{2} \) mile. Narrow as it is, it consists, throughout its length, of a central band of limestone, bordered by garnet-gneiss on each side. The garnet-gneiss is not of the contact type but is the ordinary injection gneiss which constitutes the general run of this rock. The inclusion presents precisely the same structural combination that is found southeast of Edwards, the minor synclines of limestone in garnet-gneiss on the flanks of a larger fold. This Tanner creek inclusion seems to us to unquestionably have synclinal structure. With fluid granite working its way upward along the dip it is not only easily conceivable that the bottom of such a narrow synclinal trough might readily split the ascending intrusive, but it is quite difficult to see how it could avoid doing so.

There are a host of Grenville inclusions within the Hermon sill. Most of them are too small to map on this scale, though several of them do appear on the map. Their strikes and dips are in harmony with one another and with those of the Grenville beds away from the intrusive. The granite shows little sign of having experienced the pressures which would be necessary to so sharply
fold a thick sedimentary series. It has unquestionably been squeezed. It is somewhat foliated, and the porphyritic feldspars are somewhat granulated, especially locally. The rock as a whole, however, is not much crushed, and the great number of the big porphyritic feldspars show little or no granulation. The rock has undergone a certain amount of compressive stress since its injection but nothing in comparison to what it would have experienced had it been folded along with the Grenville beds. Just how, as a result of such folding, a synclinal trough like that along Tanner creek could have come into existence as an inclusion in its present attitude, is quite beyond our powers to imagine. It seems to us quite clear that the concordance of strike and dip shown by all the inclusions points to the fact that the present surface exposures are very nearly at the extreme summit of the granite invasion, that it is practically all yet below ground, that the granite sills represent the extreme upper limit of the intrusion, that the Grenville inclusions were comparatively undisturbed parts of the old roof, the bottoms of down-folds in the overlying sediments, having almost precisely their present attitude at the time of the granite injection.

The structure shown by the sediments at the end of the sills, where they wrap round the intrusive as though pushed out of the way by the rising fluid, seem to us to point to the same conclusion. In particular, such conditions as are found at the south end of the Reservoir sill seem to us explainable on no other hypothesis. The Grenville hogback there, already described, is a structure conditioned by the upper surface of the granite intrusive. Then the thin selvage of greenish syenite there emphasizes this conclusion. It looks like a very narrow chilled border, but can not be such unless some differentiation took place within the sill, after intrusion but prior to solidification. Both bottom and top of the sill are exposed, however, and there is no sign of such differentiation aside from the chilled border. The bottom of the sill is composed of the same granite as is the top. If the sill had been originally flat-lying, intruded into undisturbed, unfolded Grenville rocks, then the evidence would be clear that no differentiation had taken place, and we should lack any reasonable explanation of the chilled border. If the intrusion took place into rocks previously folded, then differentiation in the sill would not take place parallel to the top and bottom of the sill, or rather parallel to the underlying and overlying sediments, but rather in the horizontal plane and, except for a narrow chilled border, nothing but granite would be found in the
upper part of the steeply inclined sill, that part which is today exposed at the surface, and the syenite would be found well below the surface.

It therefore seems to us that we have in the Gouverneur quadrangle an example of one of the syenite-granite bodies so common in northern New York, in many of which the evidence is absolutely clear that they represent differentiation phases of the same magma; that here the uprising magma came into a cover of closely folded Grenville; and that because of the close folding somewhat unusual results were obtained. Granite sills are not common. Granite commonly works upward rather than sideways. From the top of granite bodies numerous dikes work their way upward, but in these closely folded rocks here the rising granite utilized the bedding planes, already steeply inclined, as the easiest upward path, so that what would ordinarily have been dikes here become sills. The main body of intrusive here is entirely below ground. In these sills we have merely small uprising tassels from the main mass, into the overlying Grenville cover. The Grenville was folded before the time of these syenite-granite intrusions. The time of folding was no doubt more nearly coincident with that of the earlier amphibolite and granite intrusions, here called Laurentian.
ECONOMIC GEOLOGY

General Considerations on the Occurrence of the Ores and Minerals

The area covered by the Gouverneur quadrangle in southwestern St Lawrence county is a notable mineral district. The bounds of the mineralized section somewhat exceed those of the map itself, but the Gouverneur quadrangle is central and fairly representative of the general character of the entire district. Many of the minerals recorded in Dana’s Manual and other reference works on mineralogy for St Lawrence county may be found within the area, and some of the occurrences are not duplicated outside. Few districts anywhere in the eastern part of the country provide so much of variety and interest to the student of mineralogy and economic geology and at the same time in such accessible and inviting environment. Practically all of the important localities that are on record are opened mines or quarries or prospect workings, situated within an hour’s distance at most from the village of Gouverneur. This place is headquarters for most of the mining operations in progress in the district and the general commercial center for western St Lawrence county, which is a fertile agricultural region.

The Gouverneur area, as has been shown by Cushing in his discussion of the geology, is a part of the Adirondack province, which itself belongs really to the Laurentian region of Canada. There is no close connection between the Adirondacks and the Green mountains which are separated from them only by the Champlain basin or with the Appalachian system in general that embraces all of the other upland and mountainous parts of the State. On the other hand, no natural break intervenes between the Canadian Laurentian region and the Adirondacks; the same Precambrian formations may be traced from the interior plateau district of St Lawrence county across the Gouverneur sheet and to the Hammond and Alexandria Bay quadrangles whence they extend to the St Lawrence river and reappear on the north bank to spread out west and north over an immense tract in Quebec and eastern Ontario.

The relationship, naturally enough, extends also to the mineral occurrences. The closest similarity exists in regard to many of the deposits, like those of talc, pyrite, zinc and iron ores, found in the Adirondacks and the part of Canada north of the St Lawrence river, evidencing a certain uniformity of geological surroundings. The comparison, however, may not be pushed so far as to indicate
an identity of conditions in the two regions, for the Adirondacks cover a small area in comparison with the whole Laurentian highland and are lacking in representatives of some of the important formations of the area to the north, as well as, of course, their associated mineral deposits. There is no basis on geological grounds for expecting deposits of nickel, cobalt, silver or gold in the Adirondacks, such as give so considerable support to the mining industry of eastern Canada.

The rocks of the Gouverneur district belong to the same formations that characterize the geology of the interior Adirondacks, as has been explained already in the preceding section of this report. Although there is thus no line of demarcation existing anywhere between the highland proper and the area under consideration which has a surface of low relief mainly between the limits of 400 and 800 feet above tidewater, there is a considerable difference apparent in the general distribution of the rocks when their outcrops are outlined on the map. The interior Adirondacks are constituted predominantly of the hard massive rocks of igneous origin, that is, granite, syenite, anorthosite and their gneissic phases whereas the limestones and schists of the Grenville series play a subordinate role. In St Lawrence county the relations are so far changed that the sedimentary beds of limestone (marble) schists, and feldspathic or quartzose representatives of the Grenville have an important share in the surface geology, spreading out around Gouverneur in several considerable belts that altogether cover more than one-half of the surface of the quadrangle. The basic igneous rocks of the gabbro-anorthosite division are unimportant areally, and the main representatives of the igneous class are granites and their offshoots of pegmatite.

There are probably at least two varieties of granite of separate periods of intrusion represented in the district, but by far the predominant sort is a reddish coarse variety which Cushing calls the porphyritic granite, distinguished by a considerable content of black mica, a nearly massive habit, and rather large pink or reddish feldspars. It is a fairly acid or quartzose rock and shows marked powers of penetration and absorption in contact with the Grenville schists and gneisses. It intrudes and permeates practically all of the Grenville rocks except the limestone, wherein there are only occasional pegmatite dikes, and is much the most conspicuous individual element in the geology of large stretches of the area through its appearance in innumerable small bosses and networks.
of dikes and stringers that always stand out in the natural ex-
posures on account of their fresh appearance and contrasting color. The map can give no adequate representation of the widespread development of the granite since the individual outcrops are usually too small to be indicated on it. In the aggregate these small off-
shoots bulk very large, so that the granite really is a greater factor in the geology of the district than appears from the areal map.

There can be no doubt that the porphyritic granite has played a considerable role as mineralizer; it has been indeed the most effective agent of all the igneous magmas in that capacity. Its powers of injection and assimilation are everywhere in evidence among the older schists and gneisses, and on contact with the limestones it has often effected a complete breaking up of the carbonates, with the formation of secondary silicates like diopside, tremolite, horn-
blende, phlogopite, tourmaline etc. That the solutions and vapors given off by the magma in the cooling process circulated for considerabe distances from their source may be held as certain and it is to them no doubt that the veins and bodies of quartz and peg-
matites which occur throughout all of the Grenville are to be re-
ferred, as well as the scattered occurrences of the silicate minerals in the limestone. Their agency in the formation of the zinc and pyrite deposits is not so clearly evidenced perhaps from field obser-
vations, but it is made fairly certain by studies of the mineral asso-
ciations as will be brought out later in the description of these ores.

Most of the mineral occurrences of secondary type are the re-
sult of this igneous activity, although it does not necessarily follow that all of the chemical substances represented in their constitution were contributed by the granite. The solutions and vapors that were given off were powerful solvents, capable of attacking the existing mineral combinations in the rocks through which they circu-
lated and setting up new ones more stable under the prevailing physical conditions. In some instances probably the changes have involved little in the way of new contributions, the solutions having collected the various materials during their progress within the country formations. Thus the common mineral impurities of the limestone are combinations of lime, magnesia and silica chiefly, which all may have been contributed by these rocks, which usually contain small amounts of silica, alumina, magnesia, iron etc., be-
sides lime, in their normal development. There is some question as to the actual transference of material from the igneous magmas in the formation of silicates like tremolite, diopside, enstatite, phlog-
opite and others of their class, which occur within the calcareous
beds. It seems likely, however, that at least much of the silica required for the formation of such compounds has been contributed by the igneous materials; the wide distribution of vitreous and massive white quartz, certainly to be traced to the granite quite as much as the pegmatite, is a noticeable feature and shows that the solutions carried large amounts of free silica available for combination with bases. For the more complex silicates, and particularly those containing such elements as fluorine, chlorine and boron as essential ingredients, it is even more necessary to assume the participation of magmatic materials.

The mineralization may be characterized in general as of contact type. Not always are the occurrences along the margin of the granite, as would be inferred perhaps from the use of the word "contact" in this connection, but they are nowhere very remote from bodies of that rock or its offshoots. The term is here used in the broad sense to indicate rather the process than the locus or position of mineral development. From the widespread occurrence of granite dikes and stringers and the manner in which the magma has drenched the older Grenville silicate rocks, it may be inferred that there are large bodies of granite below the surface—the present exposures representing only the upper outlying parts of the intrusion which mainly cooled and solidified deeper down in the earth.

Of all the rock formations, the Grenville beds, and especially the limestones, are most susceptible to the action of mineralizing agencies. This is owing partly to their physical character, incident to their jointed and bedded condition with the numerous openings thus provided for the admission and circulation of waters, and partly to their chemical nature which renders them more easily a prey to chemical reaction and solution. The limestones are particularly prone to chemical attack, whereas the schists and gneisses, composed largely of quartz and silicates, are more resistant to this influence.

**Geology in Relation to Prospecting and Mining**

For the location and preliminary field study of the mineral deposits of the district, the most valuable guide is the geological map which accompanies this report. Upon the nature of the rock formations depends primarily the character of the mineral deposits associated with them. This is a principle that applies very generally to mineralized areas. It is also a matter of observation that particular
localities are closely related to certain special geological conditions, such as may be supplied by local variations in the rocks in regard to composition and structural features. Of first importance for the prospector, however, is the discrimination of the rock type, for which the geological map provides the general basis.

Broadly, the rocks of the Gouverneur area fall into two main groups, according to their method of origin, the one sedimentary and the other igneous. The first group comprises the Grenville series, and is made up of former sandstones, limestones, clays and silts, now represented by quartz schists, crystalline limestones and dolomite, and various gneisses of which the garnet-gneiss is a typical member. The sediments were probably formed in successive beds in an ancient sea, and they are properly grouped into a single series, the oldest of all in the district. The second or igneous group consists of the reddish porphyritic granite and its numerous pegmatitic offshoots, the fine-grained gneissic granite, and the gneissic gabbro or amphibolite. Wherever the igneous members are in contact with the sedimentary group, their relation is intrusive as far as the conditions can be determined at all.

In the preceding pages it was pointed out that the porphyritic granite has influenced the formation of certain mineral deposits. Its contribution would appear to have been two-fold: first, as the parent source of many quartz veins and pegmatites with their contained minerals, and second, as a mineralizing agent by virtue of the hot liquids and vapors that were given off by the magma in its cooling stages and that by reason of their heat and content of solvent substances, like fluorine, chlorine and sulphur dioxide, were able to take up and transport materials quite resistant to ordinary geological processes. The mineral-bearing waters and vapors circulated outward and upward from the invading magma, from regions of higher pressure and heat to those of moderate depth in which conditions may have approached those at the surface. In this circulation their solvent capacity would have diminished with distance from the granite magma; deposition of the mineral substances followed as a necessary consequence along the path of the circulations and in reverse order of their solubility. The sediments by reason of their open textures, their favorable structures, or their chemical nature, were more accessible to the movement of the mineral solutions than the igneous formations, generally speaking, and were the collecting ground for many of the deposits.

The bodies of pegmatite and quartz stand in the closest relation to the granite. In certain instances they are but a differential phase
of the granite itself, occurring within or on the borders of the separate intrusions and showing more or less gradation from the one to the other material. Such included bodies have, therefore, a rather indefinite boundary. Dikes and small bosses of pegmatite also occur in all of the other formations and particularly those of the sedimentary or Grenville series; these, as a rule, have sharp boundaries against the inclosing rocks and the boundaries often appear to have been determined by lines of weakness in the latter as represented by bedding structures, joints or faults.

A different type of deposit that resulted from the granite invasions is represented by the silicate zones within the limestone belts, especially those limestones that are of magnesian character. Where the carbonate rocks occur in proximity to the granite, they are likely to contain silicate impurities, notably tremolite, diopside, enstatite and tourmaline. In places considerable bodies of limestone have been converted into a pure tremolite schist. Such silicate zones would appear to have been formed by a mingling of certain elements of the granite, particularly silica (also iron, boron and fluorine when present), with the bases, lime and magnesia, present in the limestones. They are contact-metamorphic deposits in the common classification of mineral deposits. An important economic product of this group is fibrous talc, which occurs in the Edwards-Sylvia lake limestone belt in intimate association with tremolite. Local alteration of the tremolite, accompanied by removal of lime and taking up of water, has produced talc, which often retains the physical characteristics of the tremolite. By a similar process of change much of the diopside originally occurring in the limestone has been converted into serpentine.

The zinc-pyrite deposits of the Edwards district that quite recently have come into prominence for the production of zinc are traceable to the mineralizing influence of the granite exercised during a later stage of the cooling process than the contact-metamorphic deposits. They favor the outer borders of the limestone belt and the more important deposits thus far opened lie within zones of the country rock that contain abundant silicates. Some occur in close proximity to talc. Besides silicates and carbonates, the gangue contains small amounts of barite and more or less free quartz. Of considerable practical importance for the milling and smelting of the ores is the small content of lead minerals, galena

\[1\] Smyth, C. H., Jr. The Genesis of the Talc Deposits of St Lawrence County; N. Y. Sch. of Mines Quart., v. 17, 1896, p. 333-41.
being present in very minute proportions. As is explained in the section on the zinc deposits (page 90), the ores are in the nature of replacements of the wall rocks, the ore-bearing solutions having effected a chemical interchange between the carbonate minerals and the metallic sulphides. By this process of deposition no large openings were required to give room for the ore-bodies but the waters found their way along narrow fissures and joints, which they widened by solution of the carbonate minerals as they precipitated their content of sulphides. The ores are characterized by a close texture and uniformity of size of the metallic minerals, the individual particles being approximately of the same size as the minerals of the gangue. The ores were deposited at considerable depths and were later exposed in their present positions by erosion of the limestones. The most favorable ground for their occurrence, other things being equal, is along the edges of the limestone belt, within the first few hundred feet from the contact with the granite.

Pyrite, alone or associated with pyrrhotite, is found in workable bodies in the Grenville quartz schists and garnet-gneisses; its derivation probably has been somewhat analogous to the zinc-pyrite ores. The gneisses and schists that carry pyrite in abundance have a considerable admixture with granite. It is not demonstrable with certainty that the granite has contributed the iron for the production of all the pyrite — or the zinc for the preceding group of deposits — but its influence in stimulating and increasing the solvent effect of the circulations that accomplished the mineral concentration may at least be accepted as fairly established.

The relation between the larger features of the distribution of the mineral deposits on the one hand and the nature of the containing formations on the other needs hardly to be further emphasized. The hosts of practically all the valuable ores and minerals are the Grenville sediments. Pegmatites and quartz veins occur in the igneous country, but even they are rather more prominent in the Grenville as offshoots of the granite. Limestone is the distinctive country for talc and zinc; the sedimentary quartz-silicate rocks for pyrite, pyrrhotite and graphite.

If the conditions surrounding the concentration of the ores and minerals have been correctly interpreted, certain deductions that are of importance to the mining industry may be made as necessary sequence to those conditions. The concentration in general has been effected by hot ascending solutions having their sources at
Figure 14 Section across the limestone belt at Edwards, showing folded relations of the Grenville strata.

The central belt is a syncline, bordered by compressed anticlines.
considerable depths. As a consequence the deposits are not likely to be shallow in the sense of being limited to a restricted surface zone, characteristic for ore bodies formed by downward-moving surface waters. But in the case of the zinc and pyrite ores the mineralization is possibly coextensive downward with the depths attained by the folded schists and limestones or so far downward as these maintain the same characteristics physically and chemically as they have near the surface. This view, expressed by the writer in the period of the early mining operations at Edwards, has been confirmed in part by the results of exploration to depths of over 1000 feet. Another consequence of the method of origin is the uniformity in the content of the ores and their physical make-up irrespective of the depths from which they come. This also is not usually the case with concentrations by surface waters which are apt to show marked changes within rather limited ranges of depth. The absence of vugs, caves and open fissures in connection with the zinc ores is a further characteristic connected with their manner of origin and one that contributes to economy of mining and exploration.

In the study of the field structures of the ore bodies and the country formations, it is important to note that the period of general mineralization was in the early Precambrian, subsequent to which was a long period of erosion that terminated only with the opening of the Cambrian period and the deposition of the Potsdam sandstone. This prolonged erosion was deep enough to plane down the surface to a nearly uniform level, cutting away a great but undetermined thickness of rocks. The folded structures which are exemplified so well in the Grenville strata indicate that the region before planation must have been fairly elevated and mountainous, and it is probable that many thousands of feet of rock are represented in the eroded continuations of the folds indicated by the present attitudes of the rocks. Any superficial mineral deposits that existed previous to the erosion period were necessarily carried away and dissipated.

The Potsdam sandstone which is found here and there resting in nearly horizontal beds upon the Precambrian formations is but a remnant of what was once a thick cover of early Paleozoic strata that included various shale and limestone members as well as sandstone. It is only in recent times that the Precambrian surface has reappeared from under the mantle of the bedded strata. This period of burial was one of almost stagnant conditions for mineralization in the Precambrian within the Gouverneur area. There were no
new deposits formed of any importance, and those already existing were little modified during the interval.

Consequently the occurrence of Potsdam has little or no bearing upon the existence of mineral deposits in the underlying Precambrian. There is the same likelihood of finding them under the sandstone as in the exposed formations, other things being equal.

List of Minerals and Mineral Localities

Preliminary to the description of the deposits of economic importance, brief mention will be made of the various minerals which have been noted as native to the district and of their local occurrence. The list of mineral species for the district embraces a large number that have no special value industrially, as in fact the useful minerals generally constitute only a small proportion of those actually known. The vicinity of Gouverneur has provided a great array of minerals in the way of crystallized and uncommon physical forms, and not a little that has served as type material for purposes of scientific description or illustration, so that an enumeration of the individual species with information of their occurrence may prove serviceable to the student and collector.

In the compilation of the mineral occurrences information has been drawn to some extent from published sources, notably Dana’s Manual which is valuable principally for the data about the early discoveries, from the reports of the First Geological Survey of New York State and particularly those by Emmons and Beck, and from Whitlock’s New York Mineral Localities. The last-named work is the most complete in its references to the mineral occurrences of the district that has appeared up to the present time. The information thus made available has been supplemented by observations in the district by the writer in the course of a field experience that extends through a period of many years.

Although attention is restricted generally to those occurrences within the limits of the map, a few localities of particular interest that are found in the bordering areas will be included, for which Gouverneur would naturally be used as a base by any one intending to visit such places.

Actinolite. This variety of amphibole occurs in characteristic development of thin bladed and fibrous crystals in the walls of the talc mines in the town of Edwards. It has the same methods of occurrence as tremolite, the common parent mineral of the talc, and

1 N. Y. State Mus. Bul. 70, 1903.
differs in appearance only in its greenish color which is traceable to the small content of iron in ferrous form. The crystals occur in felted or matted intergrowths, as actinolite schist. The country rock is limestone, but porphyritic granite appears nearby.

**Albite.** Soda feldspar is present in some of the pegmatite bodies, as one of the essential constituents. It is associated usually with microcline and may be intergrown with it as perthite. One of the localities where both varieties are found in large crystals or masses is at the quarry now being worked for pottery spar on the road between Richville station and East De Kalb, 3 miles northeast of the former place.

**Amphibole.** The members of this mineral family are mentioned under their specific names, as far as they are recognized. (See actinolite and tremolite.) Various aluminous amphiboles are represented, of which the exact composition and type has not been determined. One of the common forms is of greenish color in prismatic shapes, to be classed probably with the variety pargasite. It is found in the limestones, often associated with tremolite and diopside. Localities are the Calvin Mitchel farm in East De Kalb, the zinc mines at Edwards and the vicinity of Talcville. Darker green or black amphibole is an important ingredient of the gneisses; one of the gneissic rocks developed on the borders of the Edwards limestone belt consists largely of this mineral and is described in the first part of the report under the name "amphibolite." It is believed to be derived from gabbro, in which case the amphibole is probably derived from an aluminous pyroxene. Black or green amphibole is also an accompaniment of some of the Grenville schists.

**Apatite.** Crystals of apatite, greenish or reddish in color, small to fairly large in size, occur in the crystalline limestones, notably in the marble quarries north and south of Gouverneur. The quarries just southwest of the town have supplied examples of the usual six-sided prisms, terminated by the unit pyramid, 4 to 6 inches long. Beck records a crystal nearly a foot long and weighing 18 pounds from the Robinson farm, town of Hammond, which is outside the limits of the map. This locality is perhaps the same as that listed by Whitlock as near DeLong's mills.

**Asbestos.** Fibrous tremolite, or brittle asbestos, is not uncommon in the walls of the talc mines, one or both of which may be constituted of tremolite schist. It is also to be seen in other limestone areas, as a development of the normal tremolite. The flexible
asbestos, or chrysotile, is an occasional accompaniment of the mas¬
sive serpentine disseminated through the Edwards limestone. The
occurrences are of no commercial interest.

Barite. In the zinc ores of the Edwards district barite is gen¬
erally present in the form of small crystals or grains intergrown
with the calcite. In the ore-forming process it has been partly re¬
placed by the sulphide minerals. The presence of barite is not easily
detected in the examination of the ore although it shows readily on
crushing and separation as practised at the mill of the Northern
Ore Company, which reports the presence of 1 to 3 per cent of
barite in the run-of-mine product. Large crystals are reported to
occur at Osborn lake, in the western part of De Kalb township.

Biotite. This occurs widely in the granites, pegmatites and
gneisses of the district as an essential component. Large plates are
obtainable in the coarse-grained rocks. It has no commercial value
for electrical purposes owing to the iron content and is too nearly
opaque to be useful for stove mica.

Calcite. Although abundant in the limestones and marbles of the
district, good crystallized specimens are not common. The noted
localities, of which there are many in western St Lawrence county,
are all off the Gouverneur sheet; the Rossie and Hammond lead
mines which are reached in a short drive from Gouverneur, have pro¬
vided great quantities of crystallized material, some clear and almost
of optical grade. Descriptions of these will be found in Whitlock’s
Calcites of New York.¹

Chalcopyrite. This is an occasional ingredient of the pyrite
deposits, but never an important one.

Datolite. The only occurrence that has been noted is on the
Calvin Mitchel farm, in the town of De Kalb, mentioned in the fol¬
lowing paragraph. It is rather uncommon at that place.

Diopside. Green pyroxene belonging to the diopside species
is prevalent as small disseminated crystals or aggregates in the lime¬
stones, particularly those of the Edwards district. It is the parent
mineral of the serpentine, characteristic of much of the limestone,
and in thin section is observed to occur as nuclear particles sur¬
rounded by serpentine.

Transparent, well-formed crystals of gem quality occur on the
Calvin Mitchel place, 3 miles northeast of Richville Station, town of
East De Kalb. The prismatic crystals measure as much as 2 or 3
inches in length by an inch across, with single terminations. They

¹ N. Y. State Museum Memoir 13, 1910.
occur along crevices in a quartz-banded limestone, associated with a green amphibole, and rarely with datolite. They were collected in quantity by Mr Mitchel and sold to mineral collectors and for gem cutting; the cut stones have a light green to grass green color and considerable brilliancy, almost that of peridot. Crystals from this locality are figured in Dana’s Manual. They are unique in perfection and quality of color for New York State. A few crystals have also been obtained from the George Foster farm, 2 miles east of Richville station.

**Dolomite.** A subordinate ingredient of most of the crystalline limestones or marbles of the district, where it is intergrown with calcite and only distinguishable by chemical analysis of optical tests. The Gouverneur marble contains 10 per cent or so of the mineral and the Edwards limestone considerable more. The white marble near the Rock Island School, 3 miles north of Gouverneur, quarried for building stone, is practically pure dolomite, containing about 20 per cent of magnesia (21.7 per cent required by formula). This locality is given further mention in the section devoted to quarry materials.

**Enstatite.** This mineral is commonly recorded in the works on mineralogy as occurring with the talc of Edwards and Fowler, associated with tremolite. It is an uncommon mineral, however, in the writer’s observation which extends to all of the principal talc mines. The only place where it has been found in quantity is a prospect one-half mile north of the Edwards zinc mine, which shows a small outcrop of enstatite schist, made up of an intergrowth of bladed crystals that have a bronzy appearance and are partially altered to talc. In general, tremolite is the ancestral source of the talc, not pyroxene.

**Fluorite.** This is rather rare for this district, but common in the Rossie and Macomb lead mines, and in one or two places occurs separately in masses or crystal aggregates in the limestone. The town of Macomb has yielded some fine exhibit specimens of bright green fluorite, of which a large quantity (15 tons) came from a locality discovered in 1889, and showed cubes of the mineral up to a foot across. Examples of this occurrence are in the State Museum at Albany. In the Gouverneur section it is a minor constituent of some pegmatites.

**Galena.** The zinc ores of the Edwards district contain a small proportion of lead sulphide or galena in mechanical admixture with the pyrite and blende. At the Edwards mine itself, it is only occasionally present in visible form, but specimens from the Williams shaft on the northern end not uncommonly afford cleavages of the
mineral that measure up to an inch across. That it is a component of all of the ore to the extent of a fraction of a per cent is evidenced in the mill treatment, for a band of the gray galena invariably appears on the concentrating table above the sphalerite. On the Balmat farm in the southwestern part of the district there is a vein in which galena constitutes an important ingredient and which once was worked for this mineral, rather than for zinc. This occurrence is reported to carry a little silver.

The principal occurrences of galena in St Lawrence county are a few miles out of Gouverneur and off the limits of the map, in the towns of Rossie and Macomb. They consist of fissure veins, from a few inches to 2 or 3 feet wide, intersecting the Precambrian gneisses and crystalline limestone and in one or two places they extend upward into the Potsdam sandstone. The gangue consists of calcite with some fluorite and barite, while chalcopyrite, sphalerite and pyrite constitute with galena the metallic ingredients. From the vugs and cavities in the veins have come beautifully crystallized examples of these different minerals, which are scarcely obtainable at present owing to the caving and filling of the shafts. The Coal hill vein near Rossie village is said to have produced 1625 tons of lead in the early period of mine operations which started about 1836 and lasted for about 15 years. The Victoria or Pardee mine, in the same vicinity, also was worked quite extensively, the vein having been followed to a depth of 300 feet and a mill and smelter having been erected for treating the output. In the town of Macomb galena occurs at Mineral Point on Black lake, an old mining locality, also on the farm of F. E. Turner, 3 miles north of Brasie Corners, and on the Downing, Pennock, and Jones places near Pierces Corners. The small size of the veins precludes their practical operation for lead at the present time; but their relative content of galena may be fairly high.

Garnet. Garnet is common in the Grenville gneisses and on granite contacts. It is a constant ingredient of one member of the Grenville, a garnet-gneiss that occurs in the southeastern part of the quadrangle, north and south of Edwards village, the garnet being distributed in small crystals and roundish particles of pink color in a mixture of feldspar, quartz and mica. Occasionally the garnet attains half an inch in diameter, but usually is much smaller. The development of garnet as a reaction mineral in the vicinity of granite and pegmatite is a widespread phenomenon and it is hardly necessary to refer to separate localities.
A band of very rich garnet rock, about 2 miles north of Gouverneur on the road to Peabody bridge, has been the object of some mining activity. About 1902 the Gouverneur Garnet and Lead Mining Company started operations in the locality with the purpose of producing garnet for abrasive uses. The garnet is of pinkish color and probably almandite; it occurs in round particles that average not over one-quarter of an inch diameter but are very plentifully distributed so as to constitute fully one-fourth of the entire rock mass. The other ingredients are bright green and the combination of color makes the rock a striking one when seen in fresh specimens. It is no doubt a development of the Grenville gneisses and resembles very much one of the Grenville rocks commonly associated with the graphite beds of the eastern Adirondacks. The rock is richer in garnet than that available in most places for quarrying, but the mineral is rather too fine to serve the purpose of an abrasive, after it has been submitted to the necessary reduction required for its separation. The quarry has not been worked for a number of years.

**Graphite.** This mineral is quite common in the sedimentary schists of the Grenville series, in which it is disseminated in small scales or flakes through the body of the schists, constituting perhaps 2 or 3 per cent of the mass. The schist belts of the Edwards-Sylvia lake district and of the Gouverneur pyrite belt exemplify this method of occurrence. It is also occasionally to be seen in the crystalline limestones or marbles. So far as is known, there are no deposits within the quadrangle that seem to merit attention from an economic standpoint; only one or two graphite deposits in St Lawrence county have been worked to any extent, the principal operations centering on an occurrence of graphite schist near Popes Mills, town of Hammond, which yields a crystalline product of finer grain than the eastern Adirondack graphite. The product from this mine has been sold for paint purposes.

**Greenockite.** The zinc ores from the Edwards district have been observed in a few instances to have a coating of a greenish-yellow earthy substance that reacts for cadmium and has been identified as the sulphide greenockite. It is found on the weathered joint surfaces as a bloom, the result doubtless of partial decomposition of the sphalerite which itself contains little more than a trace of cadmium. The presence of the mineral was first observed by the writer in the ores from the mine of the Northern Ore Company. Good specimens were later collected from the Rhodes prop-
Hematite. Deposits of red hematite are associated with the Grenville schists and limestones and have been the object of mining in years past. In some instances they are simply the gossan or weathered outcrop of the pyrite and pyrite-sphalerite ores; this seems to be true of the ore localities in the vicinity of Fullerville and Sylvia lake which once were worked for the supply of the Fullerville furnace. About a mile east of Fullerville, in the sand terrace which here is underlain by limestone, is an old shaft that has afforded some soft earthy and hard hematite, with more or less white quartz admixed with it. Another locality is the zinc prospect on the Dominion Company’s property, just east of Sylvia lake. A soft earthy hematite was mined here some 30 years ago, the principal opening being a pit on the outcrop of a lens or shoot of the ore which in depth became charged with the sulphides of iron and zinc and thus unsuitable for smelting. Later exploration showed that the change progressed with depth, so that practically unaltered sulphides were taken in the prospect shaft at a depth of 100 feet or a little more. The occurrence of hematite within the limestone belt, may serve to indicate the presence of sulphides.

Other deposits of hematite occur in the Grenville schists, as at Ore Bed school, in the southern part of DeKalb township, and near Fowler. The schists in which it is found are pyritic, but the ore itself is free of sulphur and not apparently directly related to the pyrite. The occurrences are of little economic importance in themselves, although they illustrate a type which has played a considerable rôle in the iron industry of this section. The mines of the Antwerp district are found in association with pyritic Grenville schists and along the contact of the schists and crystalline limestone, the ore being a replacement of these rocks formed through the agency of underground circulations. The principal mines are situated along a belt that begins just north of Antwerp village and extends northeast, parallel with the R. W. & O. railroad, to near the Rossie-Gouverneur town line; they include the Dickson, Old Sterling, Morgan, Keene, Caledonia and Clarke mines, from which altogether a large quantity of ore has been mined.

Limonite. Bog iron ore abounds in many parts of St Lawrence county, where the sluggish streams and swampy areas favor its accumulation. The towns of Gouverneur, Fowler, Canton, and Brasher have yielded furnace material in some quantity during the
time when local smelting operations were in progress 40 or 50 years ago. Limonite of spongy nature occurs as gossan on the outcrops of some of the zinc deposits of Edwards, notably the White property of the Northern Ore Company.

**Magnetite.** This mineral is an ingredient of the crystalline silicate rocks, particularly the granite and schists, but it is not known to occur in workable amount anywhere in the quadrangle. The large deposits of Benson Mines are off the limits of the map to the southeast of Edwards.

**Microcline.** This is an important mineral in the porphyritic granite and its pegmatite offshoots. It is often intergrown with albite in perthitic arrangement, and is the principal feldspar in the quarries near Bigelow, which are described separately in this report.

**Muscovite.** Although this occurs in granite and to a minor extent in the pegmatites, it is not of economic importance.

**Oligoclase.** Occurrences of this mineral are noted in association with some of the granite and pegmatite, in the same manner as microcline, but in smaller amounts.

**Pyrolusite.** Good specimens of fernlike crystals of pyrolusite are found as an incrustation of the talc schist in the Edwards district. No. 2½ mine, Talcville, yields abundant specimens.

**Pyrite.** The occurrence of this important mineral is described separately. It is widespread in certain quartz schists of the Grenville.

**Phlogopite.** This occurs in small scaly crystals rather commonly in the limestone of Gouverneur and other sections, and, in larger sheets as a contact mineral associated with other secondary silicates like amphibole, wernerite, diopside and titanite. Sheets measuring 6 inches or more across were observed by the writer on the waste dumps of No. 2½ talc mine at Talcville.

**Pyrhotite.** This accompanies pyrite in some of the deposits found in the Grenville schists. It is more particularly abundant in the deposits outside of the Gouverneur quadrangle and notably those at Pyrites, south of Canton, and at the Laidlaw prospects, near Oxbow, southwest of Gouverneur. It may carry a little nickel.

**Quartz.** Various forms occur in great abundance. It is found crystallized in vugs and fissures, and particularly in the Grenville quartz schists which constitute the wall rocks of the pyrite deposits. Handsome crystals have been taken from the mines of the St Lawrence Pyrites Company at Stellaville, near Hermon, just off the Gouverneur sheet. The crystals are simple combinations of the unit
prism and pyramid. Massive quartz, white or vitreous, occurs very widely in veins that intersect all of the rocks and are most common around the borders of the porphyritic granite. The quartz has the characters of magmatic quartz; it appears in practically pure bodies and in combination with feldspar as pegmatites of varied composition. The occurrence of quartz in the Grenville limestone where it produces banded and ribbed structures is described in the earlier part of this report. The limestone on the borders of Sylvia lake especially abounds in quartz which stands out as white hummocks and reefs above the surface.

Chert and jasper are occasionally in evidence around the zinc deposits of the Edwards district. A considerable body of chert occurs on the limestone ridge that is mined by the Northern Ore Company, just north of Edwards.

**Serpentine.** This mineral abounds in the Edwards limestone belt as nodules and bunches enclosed by the carbonates. Most of the serpentine, as shown by Smyth, is pseudomorphic after diopside, whereas talc, the other important secondary mineral in the limestone, is derived from tremolite. A peculiar whitish serpentine, seemingly of low iron content, is found in a quarry in the limestone area near Peabody bridge, north of Gouverneur. According to local accounts, the mineral was thought to be talc and some of it was ground and sold for the same purposes for which talc is employed. It is noticeably harder than talc and has rather an oily luster.

**Sphalerite.** Occurrences are noted in the lead veins of Rossie and Macomb as an accompaniment of galena, pyrite and chalcopyrite. In the Edwards district it is associated with pyrite and occurs in replacement bodies in the Grenville limestones. These are described elsewhere under their own title.

**Talc.** One of the important economic minerals of the Gouverneur district is talc. It is reserved for special description.

**Titanite.** Fair-sized recognizable crystals of titanite are found in some of the limestone-granite contacts, as near the Gouverneur marble quarries south of the village and in the vicinity of No. 2½ talc mine, Talcville. It is associated with diopside, tremolite, wernerite and tourmaline.

**Tourmaline.** This is quite common in white, brown and black crystals, as a sporadic ingredient of the limestones where it has been

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formed by contact action with the porphyritic granite. Perhaps the best known occurrence of this type, from which have come most of the museum specimens that bear the locality name Gouverneur, is on the Reese farm, 2 miles southwest of Richville, on the Rock Island School road. It is described in some detail by Cushing on page 20. Good crystals of brown color are also to be had from the Rylestone marble quarry, southwest of Gouverneur. The black variety is a common accompaniment of the pegmatite bodies, all over the district, so widely scattered that specific mention of the localities seems unnecessary. As a constituent of the Grenville gneisses it occurs in various colors and locally may form 50 per cent of the entire rock mass. (See page 24.)

Tremolite. This member of the amphibole group is abundantly developed along the borders of some limestone areas, particularly the Edwards-Sylvia lake belt where great bodies of nearly pure tremolite in the form of crystalline aggregates appear along the contact and for some distance toward the interior of the belt. It is usually white in color and developed in long blades or needles without crystal terminations. The crystals are so interlaced that they make a very tough rock, although in the mass the latter appears to be of schistose structure. Bands of the tremolite may be traced for long distances parallel with the strike of the limestone. All of the talc mines are situated along these bands, with the tremolite forming one or both walls of the deposit.

The pink or purplish form of tremolite, called hexagonite, is a handsome mineral which occurs in the walls of the mines at Talcville, particularly on the southwestern end, and in the mines near Sylvia lake. Large masses of it are still available in the rock dumps of the old United States Talc Company's mine.

Vesuvianite. The only locality so far recorded for this mineral within the map limits, is 1 mile south of Gouverneur, probably one of the marble quarries. The locality is mentioned by Whitlock.¹

Wad. This mineral is found in association with bog limonite in some of the Edwards and Gouverneur occurrences.

Wernerite. Sporadic occurrences of wernerite as a contact mineral are reported in the Grenville limestones. It is observed at Talcville and in the Gouverneur marble quarries.

DESCRIPTION OF IMPORTANT MINERAL DEPOSITS

Zinc Ore

Sphalerite occurs in commercial quantity in the vicinity of Edwards, Talcville, Sylvia lake and at other places within the limestone belt that stretches across the southeastern corner of the Gouverneur quadrangle. Its distribution broadly conforms with that of the talc which particularly favors the bordering zone of the limestones next to the granite and amphibolite that limit the limestone on the north and south sides.

Mining of zinc in this district began in the spring of 1915 and has been in continuous progress since then. The principal operations have been carried on by the Northern Ore Company whose mines and mills are situated just outside of the village of Edwards on the Trout lake road. This property was first prospected and developed by T. M. Williams, who about 1903 was in charge of iron mining operations in the Antwerp district and had his attention called to the uncovering of zinc ore on the Todd farm, a part of the properties taken over later by the Northern Ore Company. Mr Williams visited the place and recognized the possible importance of the occurrence. In association with the Northern Ore Company, he undertook systematic prospecting work which was continued for a year or more until operations were suspended on account of legal entanglements that were not dissolved until about 1910. The development of the deposits was then resumed, but it was not until 5 years later that mining began in a systematic manner, after various trials with processes for the separation of the sphalerite and pyrite.

The Edwards deposits are only a part of the series of ore bodies which occur in the limestone between that place and Sylvia lake. They are the single active producers, however, out of the total of a dozen or more of occurrences, that have been discovered up to the present time. No doubt, others will be brought into operation in time and there seems to be every prospect that the district will continue for many years to contribute an important quota to the mineral output of the western Adirondacks.

Although zinc mining is relatively a new industry for this region the presence of sphalerite has been known for a long time, in fact since about 1835. In the reports of the First Geological Survey of New York, Ebenezer Emmons mentions the Balmat farm (wrongly
Folding and banding of impure Grenville limestone, Edwards.
Plate 14

Nodules of talc with serpentine rims in the ore-bearing limestone. Smaller grains of serpentine disseminated throughout the rock which carries sulphides so as to form a lean ore.
called Belmont) in the vicinity of Sylvia lake, as a locality for sphalerite and galena. At that time zinc was of limited importance as a metal and the ore did not warrant mining for lead alone.

The ores of the Edwards district do not seem to conform to any particular geological horizon in the Grenville limestone, but are associated more especially with those beds of the limestone that contain large amounts of silicate minerals and other impurities. The presence of tremolite and diopside and their alteration products, serpentine and talc, as well as vitreous and cherty quartz, is generally to be noted in the vicinity of the deposits. There is thus more or less close relation physically between the distribution of the talc and the zinc ores, both occurring in the impure beds that usually characterize the bordering zone of the limestone belt.

The ore bodies show much variety in their form and structure. On the surface the ore appears as bands or stripes set off more or less sharply from the wall rock, and again as indefinite patches of sulphides which become richer toward the middle and may grade into more or less solid bodies of the metallic compounds. Not infrequently the locus of ore deposition seems to have been determined by a fissure or crack within the limestone, as the ore may be seen to follow such opening more or less consistently and to be bounded by parallel walls. Underground the bands may appear to have the regularity of veins, but in a large way the ore pinches and swells and winds around quite without rule. In the mines at Edwards and Hyatt which are the only ones which have been opened to any considerable depth, the bodies may be described as lenses and shoots of ore, modified by rolls and pinches that evidently have resulted from compression subsequent to the ore deposition. In the mining of the ore it is frequently noticed that one of the walls is smooth, and free of inclusions of sulphides, while on the other side stringers and wisps of ore make off into the limestone for some distance, or may surround blocks of the limestone so that the contact on that side is quite irregular. On the free side a selvage of clay and taly decomposition products may intervene between the country rock and ore, and this often serves as a water channel.

The ore is of compact, even-grained texture, with few openings or vugs, such as are found in ores occurring in open fissures deposited under surface conditions. Physically, it resembles the limestone in so much as the sulphides have about the same grain as the carbonates and the silicates appear in the ores much as they
do in the unmodified limestone. The sphalerite is accompanied by more or less pyrite and the particles of both are approximately of the same average size, appearing in rounded or subangular grains, never as well-rounded crystals. The grain is apt to be somewhat coarser in the high-grade ores such as are exemplified by the well-defined bands or lenses, than it is in the disseminated leaner ores in which the sulphides are scattered through a ground-mass of carbonates. Samples of rich blende show individual cleavage surfaces an inch or so across, but in the average the diameter is not much more than one-fourth of an inch.

The sphalerite commonly belongs to the iron bearing variety and has a dark brown to black color. It is the typical black jack of the western mines. An analysis of a picked sample of sphalerite from the Northern Ore Company’s mine, made in the laboratory of that company, gave the following results for the chief constituents: zinc, 60.61 per cent; iron, 4.91 per cent; sulphur, 32.73 per cent; Sum 98.25 per cent. This corresponds to 90.30 per cent zinc sulphide molecule and 7.73 per cent ferrous sulphide molecule, reckoning all of the iron in that form, with 0.2 per cent sulphur in excess. It is probable that some of the iron should be calculated in terms of pyrite rather than the monosulphide, but a small excess of sulphur is demanded no doubt in combination with lead and other metallic substances. It would appear that the blende normally carries 4 or 5 per cent of metallic iron.

Analyses of the zinc ores, representing the average product of the Northern Ore Company’s mines for periods of a month each, are presented in columns 1 and 2, below. An analysis of a picked sample of the richer ore is given in column 3. The first two analyses are from the company’s laboratories at Edwards, and number 3 has been made by R. W. Jones in the State Museum laboratory.

<table>
<thead>
<tr>
<th></th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>21.47</td>
<td>18.52</td>
<td>5.69</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>4.17</td>
<td>12.12</td>
<td>3.65</td>
</tr>
<tr>
<td>CaO</td>
<td>9.34</td>
<td>11.76</td>
<td>1.45</td>
</tr>
<tr>
<td>MgO</td>
<td>13.17</td>
<td>15.04</td>
<td>.61</td>
</tr>
<tr>
<td>BaO</td>
<td>2.75</td>
<td>1.52</td>
<td>1.46</td>
</tr>
<tr>
<td>CO₂</td>
<td>n. d.</td>
<td>n. d.</td>
<td>n. d.</td>
</tr>
<tr>
<td>H₂O</td>
<td>n. d.</td>
<td>n. d.</td>
<td>n. d.</td>
</tr>
<tr>
<td>Zn</td>
<td>21.47</td>
<td>18.52</td>
<td>51.43</td>
</tr>
<tr>
<td>Fe</td>
<td>8.50</td>
<td>8.46</td>
<td>5.80</td>
</tr>
<tr>
<td>Pb</td>
<td>.125</td>
<td>.197</td>
<td>tr.</td>
</tr>
<tr>
<td>S</td>
<td>19.006</td>
<td>17.18</td>
<td>30.86</td>
</tr>
</tbody>
</table>

*BaSO₄*
Northern Ore Company's mine, Edwards. The ore bodies which have given the largest output up to the present time are situated within the low ridge of limestone that forms the first rise of ground just north of Edwards village across the alluvial flat or flood-plain of the Oswegatchie river. The limestone ridge is an isolated hill that lies in an embayment of Grenville gneiss. It is some 1200 feet long in a northeast-southwest direction and has a well-rounded oval contour, rising 40 or 50 feet above the general level.

On all sides except toward the southeast the limestone is bordered by gneiss, the latter rock belonging to a narrow band scarcely more than a few hundred feet wide that parallels the northern contact of the main limestone belt for several miles. Between this gneiss and the main granite border is an interval of a quarter of a mile wide that is occupied by a band of limestone similar to that of the main belt.

The relation of the gneiss and limestone seems to be that of an interbedded series. The gneiss is a dark hornblende-biotite variety sometimes carrying graphite, and in the immediate vicinity of the
mines it contains a large amount of granitic material owing to the injection and diffusion of magmatic juice from the red granite which occurs in great abundance on the borders of the limestone areas. Over considerable areas the gneiss has been practically converted into granite, the original minerals of the gneiss having been thoroughly blended with those of the igneous rock. Layers of quartzite and small bands of limestone are occasionally intercalated with the gneiss. An insight into the relations of the gneiss and limestone along the contact is afforded by the log of a diamond drill hole which was put down by the Northern Ore Company on the White property well within the limits of the gneiss and on the hanging side of the limestone belt. The section in this hole as interpreted by Cecil Pocock, former mining engineer of the Northern Ore Company, is as follows from top to bottom:

<table>
<thead>
<tr>
<th>Rock</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gneiss</td>
<td>0-153</td>
</tr>
<tr>
<td>Granite</td>
<td>153-170</td>
</tr>
<tr>
<td>Granite with gneiss inclusions</td>
<td>170-233</td>
</tr>
<tr>
<td>Limestone</td>
<td>233-325</td>
</tr>
<tr>
<td>Quartzite</td>
<td>325-342</td>
</tr>
<tr>
<td>Granite with some gneiss</td>
<td>342-473</td>
</tr>
<tr>
<td>Limestone and quartzite</td>
<td>473-566</td>
</tr>
<tr>
<td>Gneiss</td>
<td>566-715</td>
</tr>
<tr>
<td>Limestone and minor beds of quartzite</td>
<td>715-935</td>
</tr>
</tbody>
</table>

The ore bodies so far developed by the Northern Ore Company embrace several more or less distinct deposits. No. 1 and no. 2 veins outcrop in the southwestern part of the hill and are tapped by the Brown shaft which is an inclined shaft driven along the course of no. 1 vein. No. 2 vein lies in the hanging of no. 1, separated from the latter by 50 feet or more of limestone. No. 3 vein is about 600 feet northeast of no. 1 and no. 2 veins, close to the Trout lake road. It has been explored by the Williams shaft, but is worked through the fourth level of the Brown shaft by a 600-foot connection that follows the general strike of the limestone, all of the ore being hoisted through the Brown shaft. No. 0 vein lies in the southwestern part of the area on the hanging side of no. 2 vein, and is not exposed at the surface. It was first encountered in the vertical shaft which was put down after the other shafts to tap the lower workings of the Brown mine. The vein was cut on the 900-foot level and has been followed upward by raises from that level.

In shape no. 1 and no. 2 veins may be described as broad, thin lenses, which in their limited outcrops appear as bands with parallel
walls. They show well-marked boundaries against the limestone on the foot and hanging sides, like fissure fillings or veins, but against this interpretation of their character may be cited the evidence of replacement that is found all through the ore and the fact that there is no continuous selvage or parting plane along either wall. Both bodies are warped out of plane, no. 1 being arched toward the hanging side in a broad semicircular curve, and no. 2 warped to a less extent. They vary greatly in thickness in depth and on the strike. On the outcrop no. 1 was about 4 feet thick and no. 2 a little less. In depth they swell up to 12 or 14 feet in rolls, but these are succeeded by pinches which constrict the ore to a foot or less in thickness.

The White or no. 3 ore body is not so well defined on the surface as the others; its outcrop consists of a zone of limestone 15 to 20 feet thick that carries bunches and disseminations of sulphides intermixed with much serpentine. The ore is distinctly brecciated in places. In depth the deposit develops the form of a shoot which may be the result of a thickening of a lens by folding or lateral compression. The underground drift between the Brown and White workings provide a good exposure of the limestone beds which at the surface are considerably weathered, and only on view in a few places. There appears to be no structural break of any importance in the interval.

No. 0 vein which was first encountered in the sinking of the new vertical shaft, is only about 25 feet wide and 4 feet thick on the 900-foot level. It has a dip of about 25 degrees at the bottom but this increases to 60 degrees on the 800-foot level where the ore widens to 160 feet and averages fully 20 feet thick. The ore, like all the rest in these deposits, carries considerable pyrite, but this mineral is much more abundant on the foot and hanging sides than in the center of the vein.

The ore of these deposits is characterized by an almost complete replacement of the carbonate minerals so that the grade averages high. Still the tenor of zinc fluctuates considerable with the varying proportions of pyrite and other ingredients. The actual average of the run-of-mine may be taken at 18 to 20 per cent zinc, according to the mill sampling for monthly periods. This indicates a sphalerite content of 25 per cent or slightly more after allowance for combined iron.

Galena seldom appears in visible particles but is present in all the ores to the extent of a fraction of 1 per cent at least. Its general
presence becomes evident during the process of mill treatment, for a small band of gray galena always appears on the concentrating tables just above the brown sphalerite. At the Williams shaft on the north side, specimens were picked up which showed cleavage faces of galena an inch or so across, surrounded by sphalerite. These may be the result of secondary deposition. Barite occurs in small amounts although it can seldom be identified by the unaided eye. Tests indicate that it constitutes from 1 to 3 per cent of the ore. The other accompaniments of the ore are quartz, tremolite, diopside, serpentine and talc, all of which occur more or less abundantly in the country limestone.

**Webb farm south of Edwards.** To the south of Edwards, the first showings of ore are found on the Woodcock, Webb and McGill places, situated on the Fullerville road. The deposits lie along the southern margin of the limestone belt, across the valley from the Northern Ore Company’s mine, from which they are about 2 miles distant in a straight line. The existence of zinc in this vicinity was first brought to notice by A. J. Moore, formerly of Edwards, who did some prospecting there in 1914. More recently the Lux Development Company has been engaged in exploring the outcrops on the Webb place.

The ore in this section occurs along a restricted zone within the limestone, following the strike of the beds and keeping close to their contact with the gneiss. The latter is a gray, garnetiferous often rusty rock that is banded and injected by granite. It belongs to the Grenville series and here lies below the limestone, both rocks having a northerly dip at a high angle. The peculiar relations which characterize the contact in this vicinity have been noted in the discussion of the structure of the limestone belt.

The ore is found as disseminations and richer bunches, which show no sharply defined boundaries toward the country rock, but rather grade off on the edges. The sphalerite may be scattered through a band of limestone 6 to 8 feet wide, but in a very uneven way. Altogether the outcrops and prospect holes—none more than a few feet deep—occur over a distance of 800 feet along the edge of a ravine which has been eroded in the limestone on a northeasterly course.

The sphalerite is lighter in color than the ore of the Edwards mine of the Northern Ore Company, but it contains more or less iron. It is admixed with pyrite, so as to form a granular mixture of rather fine texture; occasionally pieces of coarse blende nearly
free from pyrite occur, as at Edwards. In all the ore there is considerable gangue stuff in the form of serpentine and talc nodules and unreplaced carbonates. There is so much variation that it is difficult to estimate the average tenor.

The exploratory operations have been confined to the sinking of shallow pits or shafts in three or four places. While much of the ore is of commercial grade in regard to zinc content, the quantity so far revealed is hardly sufficient to afford a basis for mining.

**McGill farm.** This adjoins the Webb place on the northeast, lying along the same ridge of limestone, close to the gneiss. The occurrence of ore is manifested in outcrop at a distance of 1000 feet or more from the most northerly opening on the Webb place. At the time of the writer's visit, in the fall of 1916, little had been done to prospect the deposit. The sphalerite is found as a dissemination within a layer of the limestone some 4 or 5 feet wide and of uncertain extent on the strike. There is little admixture of pyrite and the ore has a light brown color, significant of a minimum of combined iron. The dip of the ore band seems to be about 30° northwest. There is much serpentine in evidence and on the hanging side a little slip-fiber asbestos.

**Woodcock farm.** Continuing along the gneiss contact scattered occurrences of sulphides may be seen or are indicated by the rusty honeycombed appearance of the limestone. Two or three exposures have been made by blasting in which 6 to 8 feet of limestone more or less charged with ore has been uncovered. The gneiss lies scarcely 50 feet away. The limestone beds in this locality are ribbed by narrow bands of white vitreous quartz, so prominent in the Sylvia lake region. The occurrences stretch over a distance of 300 feet or more.

**Balmat place.** This lies just north of Balmat Corners on the Fowler road and one-half mile east of Sylvia lake. It is probably the first property in the district to have been prospected, as there is mention of the exploration of one of the bodies which it contains in the report by E. Emmons relating to the First Geological Survey in 1838. Emmons refers to the property under the name of Belmont and from his description it is evident that the object of the early search was lead rather than zinc, the latter metal being of little use in those days. The separation of the mixture of zinc, galena and pyrite proved too much of a problem for the success of the operations.
The results of the early exploration are to be seen in a shaft which was sunk on the more northerly deposit near the road, which is but a little distance from the Arnold talc mine. The depth of the shaft is uncertain, it being now partly filled with water, but is probably not over 75 feet. On the side hill below the outcrop a tunnel has been driven into the hanging so as to give access to the shaft workings and partly drain them. This may have been excavated at a later date than the exploratory work described by Emmons, but there seems to be no record of the time or of those interested in the renewal of operations. The body that is explored by the shaft outcrops at the surface to the southwest as a rusty band in limestones, ranging from a few inches to several feet thick. It can be traced for quite a distance in that direction. Underground it shows the same variation in thickness.

Some of the ore from the early operations was still to be seen recently about the shaft. In its content of galena which is fairly abundant in much of the material, it differs from the rest of the ores in the Edwards district. T. M. Williams, who was able to inspect the workings in some detail, states that the lead-bearing ore occurs only as a local phase, really as a distinct body from the main sphalerite deposit. In this event it may well be a separate ore concentration formed under different conditions and at a different time, possibly analagous to the lead ores to the north of Gouverneur. It was the galena that was sought by the early prospectors.

The zinc ore from this locality is distinguished by a prevalingly fine granular, dark metallic sphalerite which forms a groundmass for numerous larger grains of pyrite. The sphalerite particles are usually measurable by a few hundredths of an inch, while the average diameter of the pyrite is perhaps one-fourth of an inch. The ore from the more or less weathered outcrop has a loose, somewhat crumbly texture.

A secondary exploratory shaft has been put down on the Balmat property about 1000 feet to the south and east of the first, on what is apparently a parallel body on the footwall side. Little information about this occurrence could be gained at the time of the writer's visit, the workings having become inaccessible by caving.

**Streeter place.** On the trend of the more easterly Balmat deposit and across the Fowler road occurs a well-defined band of ore which can be traced for some distance along its northeasterly course. Its outcrop is on the northerly side of a low ridge of limestone, next to a small swamp under which the ore extends on
the dip with a higher bluff of limestone on the opposite side of the swamp. The tract is a part of the Streeter place, according to J. H. McLear of Gouverneur, to whom the writer is indebted for many facts in regard to the property ownership in this section.

The limestone and the ore outcrop are covered with soil and drift, except here and there, so that the full extent of the deposit and its relation if any to the Balmat leads are not certain, but it appears to be of substantial character. It has been explored in three places by shallow pits, of which the central one is the largest and deepest. Apparently the exploration was performed many years ago, and may be contemporary with the early work on the Balmat, although there is no mention of the Streeter property in the reports of the first survey which refer to the adjacent deposits.

The ore is 6 to 8 feet thick in the face exposed in the central pit, while the hanging wall is more or less charged with sulphides for a couple of feet more. The dip seems to be about 30° northwest, but there is some uncertainty in regard to the matter owing to the small extent of the exposure. The limestone in the vicinity shows contortion, so that its attitude is subject to quick changes of dip and strike; the general trend, however, is nearly northeast and the dip 30–45° northwest. The same admixture of serpentine and talc characterizes the beds as has been noted for many of the other ore-bearing localities. On the hanging side of the ore, less than one-fourth of a mile distant, is a zone of fibrous and foliated talc that has been mined for many years.

The ore has much the same appearance as that on the Balmat place, but there is no galena to be seen from microscopic examination. The blende is of dark color and metallic lustre. In texture it is finely granular, the particles averaging between one and two-tenths of an inch in diameter. The associated pyrite occurs in two forms: in part as minute particles of generally cubic habit, sometimes showing distinct crystal boundaries, and in part as coarse irregularly bounded masses which may be seen to enclose occasional sphalerite grains. The latter are perhaps secondary growths. All of the ore contains unreplaced carbonates which are usually apparent to the eye.

No prospecting has been done on the deposit in recent years, although it must be considered as one of the more promising occurrences in the district. The lack of attention may be ascribed to the difficulty—not uncommon in St Lawrence county—of securing title to the mineral rights on the property owing to their divided
ownership. There is some hope, I understand, that this impediment will soon be overcome.

**Dominion Company's property, Sylvia lake.** On the west side of the Fowler road, within a short distance of Sylvia lake, is a deposit of zinc ore owned by the Dominion Company of Gouverneur. The property lies along the branch road that turns off from the main road to the southwest, as indicated by the dotted line on the topographic maps. It is a part of the original Balmat estate, according to J. H. McLear of the Dominion Company, but represents a separate interest as to mineral rights from the Balmat mine already described. The deposits, also, belongs to a distinct ore zone, lying to the northwest of the Balmat-Streeter zone, and farther within the limestone area.

The principal opening on the property consists of a shaft put down on the side of a former pit from which iron ore was mined some 30 years or more ago for the Fullerville furnace now dismantled. The presence of zinc was suspected by reason of the pyrite that appeared in the material from the bottom of the pit at about 25 feet depth. Some samples of this ore were examined by the writer who confirmed the existence of sphalerite in a finely divided condition, along with pyrite, in a mass otherwise composed of iron oxides and vein quartz. The extreme fineness of the grain and the plentiful admixture of vitreous quartz distinguish the ore from this locality from the other occurrences in the district.

The results of exploration which has extended to a depth of 135 feet on an incline of 15° to 18° indicate that the deposit has the form of a shoot, at least in the upper oxidized portion. Practically all of the ore is comprised within the limits of the shaft workings. In the lowest part, however, the sulphides extend across the shaft on the normal northeast strike and show indications of taking the form of a band or lens in common with the other occurrences. On the surface the continuation of the same lead may be observed by outcroppings of weathered material for a considerable distance northeast of the shaft. At about 1000 feet distant the unaltered sulphides are shown in a shallow working over a width of 12 feet or more.

It would appear that the peculiar conditions encountered in the shaft are the result of purely local influence, and that if the ore continues in depth it will probably change to the ordinary type as exemplified by the other deposits in the vicinity. There has occurred a deep oxidation of the ore, with a secondary migration of some
of the zinc from the weathered part of the deposit — a result that can be traced back no doubt to preglacial times. The fact that the iron is in the form of hematite, rather than limonite, indicates a difference of conditions from those obtaining at present where limonite is the single product of weathering. Nowhere else has the process of oxidation continued to such depth and the re-concentration of the zinc been so well defined. In view of all the facts that have been brought to light it seems probable that the deposit originally was of the normal type — a mixture of pyrite and sphalerite in the form of a lens or ban — and that by reason of local fracturing or some other physical feature that favored the process, the ore was subjected to deep oxidation in a circumscribed area. As the result of this oxidation the pyrite was converted into hematite and the sphalerite probably into zinc sulphate which was then partially reprecipitated as sphalerite in contact with the sulphides lower down. The migration of the ores was effected by ground waters working along the dip of the body and their influence is to be seen also in the admixture of vein quartz that accompanies the ore. The weathering and secondary concentration may well have taken place under the cover of the Potsdam sandstone which spread over the area previous to Glacial time.

A little north of the zinc deposit occurs a band of talc which has been explored in recent years. The sulphides occur thus between two parallel talc beds, the main one being to the south on which the Arnold, Wight and Columbia mines are located and which lies on the hanging side of the Balmat-Streeter zinc deposits.

**Cemetery lot.** This locality is southwest of Balmat Corners and nearly due south of the Balmat mine, close to the border of the limestone belt. The contact of the limestone with the hard formations is quite involved in the section east of Sylvia lake, as shown in the sketch map, but on the south side it sweeps around in a broad curve at a distance of a mile or less from the lake shore. In the stretch southwest of Balmat Corners it lies just south of the Fullerville road. The limestone near the contact is very impure, showing talc and serpentine inclusions and intercalated quartz bands which in many places constitute more than one-half of the mass. Its attitude is difficult to determine, but in general it seems to follow the usual northeasterly course and to dip northwest.

The zinc showing is on the south side of the ridge which crosses the Fullerville road and which is partly occupied by a cemetery. The presence of ore here was discovered by Arthur Scott who per-
formed the little exploration that so far shows a band of rich blende and pyrite near the base of the ridge, with a width of 2 feet or a little more and of undetermined length. The strike is north-east and the dip southwest. On the hanging side a smaller band makes off into the limestone at nearly right angles.

The occurrence has interest, aside from whatever commercial importance may be attached to it, by reason of the evidence of secondary mineral growth in the ore and wall rocks, rarely to be seen in so clearly marked examples elsewhere in the district. The ore band apparently has been a locus of considerable compression and deformation; it is traversed by many fractures in which secondary carbonates, mainly calcite, have been deposited in rhombohedral aggregates. This latter material contains no sulphides. There is a second generation of pyrite which takes the form of large individuals—2 or 3 inches in diameter—that have one or more crystal boundaries and that are not intergrown with the sphalerite as are the smaller grains of the groundmass. The sphalerite itself has undergone a partial rearrangement, and the stringer of ore in the hanging wall is probably the result of a secondary migration under the same conditions which led to the recrystallization of the ingredients.

The ore is fairly rich and its character is such that it could be easily concentrated.

Rhodes place. Two or three prospects, in which a good quality of ore is revealed, are to be seen on the Rhodes farm near Talcville, directly opposite the Uniform Fibrous Talc Company’s mine and mill, just southwest of that place.

Hyatt mine. This is the second property in the district that has been developed to a producing stage and the only shipper of blende concentrates up to the present time outside of the Edwards mine. It is in the vicinity of Talcville, directly southwest of that place along the railroad (station, Hyatt) and on the east branch of the Oswegatchie which flows along the northern boundary of the property. Mining has been restricted so far to the Rhodes, Weed and Weed place, but showings of ore are found on adjoining lands.

The first locations were made here by the Dominion Company of Gouverneur. Prospecting was begun on an outcrop lying on the northwest side of the limestone ridge that marks the approximate site of the main ore zone, where later no. 1 shaft was located. About 3 feet of ore of good quality was exposed below a thin gossan, with a dip to the northwest somewhat steeper than the hill
slope. Other croppings occurred on the southeast slope across the summit of the ridge in the footwall of the first. Only trial shipments of lump ore were made by the Dominion Company. In 1918 the Hyatt Ore Corporation took a lease and started to equip the property with mining and milling plant, centering operations upon the deposit opened in no. 1 shaft. Up to the year 1922 when operations were terminated by that company the workings had been carried to a depth of 425 feet, with four levels extending on the strike of the ore. The first level at 150 feet was used as a prospecting drift to test the ground to the southwest of the shaft and was extended a distance of 750 feet. The second and third levels were each 400 feet long and the fourth was 250 feet. Nearly all of the ore milled came from this deposit. On the southwest end of the ridge no. 2 shaft was started to prospect the ground beyond the reach of the prospect drift and particularly to pick up a deposit that shows on the surface directly south of the shaft. On the north side of the ridge no. 3 shaft was put down to test a local outcrop. Minor excavations were also made on the east side of the ridge.

It would appear that the ore occurs in shoots and narrow lenses rather than in laterally extended bodies and that with the complex structures of the limestones they are difficult to define from limited exploration. The low ground to the north and south of the ridge is practically untested and seems to be the most promising section for additional prospecting. Confirmatory of this opinion is the recent uncovering by surface trenching of ore on the south side which was concealed by several feet of boulders and gravel. So far as developed it is one of the best showings in the district.

The limestone outcrops along the ridge bear evidence of local accentuation of the usual metamorphic influence shared by the carbonate materials of the district. They have been largely replaced by silicates — tremolite, talc and serpentine — and in places are seamed by white quartz or contain great masses of the latter. These are the effects, it is likely, of the granite which outcrops along the ridge marking the north side of the limestone belt. On the south side the limestones give way to concordant beds of Grenville gneiss, forming the foot wall of the ore zone. The rocks have undergone considerable pressure deformation so that observations of dip and strike show wide variations and are even obscured by mass flowage of the limestones. In the railroad cut on the northwest side there are evidences of close folding accompanied by a
Two rusty bands of limestone seem to mark here the locations of the main ore body tapped by no. 1 shaft with two talc seams overlying them. The strike here is to the northwest which carries the beds to the adjacent river below which they disappear to reappear on the opposite bank where the limestones assume their normal northeast trend.

It may be noted that talc was once mined on the property in a shaft sunk along the hanging side of the zinc body not far from no. 1 shaft. The old workings were encountered in the recent mining.

The ore from the locality is a mixture of blende and pyrite, usually well segregated and showing talc and serpentine inclusions as described for the Edwards occurrence. In the richer samples the carbonates have been largely replaced, but all gradations occur down to limestone with scattered particles of metallic minerals.

A feature of the outcrop of the main vein is the presence in places of a greenish yellow coating on the sulphides, which reacts for cadmium and would appear to be a form of the mineral greenockite. It is of earthy granular texture, not crystallized.

In its milling operations the Hyatt company adopted different methods than those in use at Edwards, following the general scheme of separation employed in the middle western districts. The first concentration was made by Joplin jigs after rather coarse crushing. Tables were used for the final process. No pyrite concentrate was made. The treatment seems to have yielded a satisfactory separation and recovery of the zinc values.

Various minor occurrences. A little prospecting has been performed by Gouverneur interests on the Davis farm, northwest of Pleasant Valley School, in the middle of the limestone belt and nearly south of Talcville. The farm is shown on the contour map at the end of the branch road which connects with the Edwards-Fullerville road just west of the school. The blende occurs as a dissemination within the limestone and as far as explored is of relatively lean character.

On the McGill farm, on the Edwards road from Pleasant Valley School, and just south of the large quartzite ridge, there are scattered bunches and disseminations of sphalerite. Some blasting was done at one locality close by the road about where the latter crosses the 700-foot contour on the map. It failed to show any defined body of ore, although samples were obtainable which carried as
much as 10 to 15 per cent zinc. This work was done by Messrs Potter and Finch of Gouverneur.

Disseminated blende and pyrite are to be seen in several places on the Austin farm, northeast of Sylvia lake.

A showing of rich blende, practically free of pyrite admixture, is to be seen directly on the shores of Sylvia lake, partly under water. The occurrence is about one-half mile southwest of the one on the Dominion Company’s lands and is reported to be held under lease by the Northern Ore Company.

At the falls on the west branch, about 3 miles above Fullerville and just off the Gouverneur sheet, an occurrence of sphalerite has been reported by J. C. Finch. There is only a small quantity of the ore in evidence, but it has interest as showing the continuation of the limestone in an offshoot of the main belt much farther south than had been supposed.


Pyrite

Pyrite occurs in the Gouverneur area in two kinds of deposits. In the one the deposits are associated with crystalline limestones and carry both pyrite and sphalerite in such mixtures that their separation is a necessary step in the marketing of the ores. This class of deposits, illustrated by those of the Edwards district, is described under zinc, which normally is the main element of value, the pyrite being considered a by-product. The second type contains pyrite alone, or pyrite in combination with pyrrhotite, but never sphalerite in quantity, and occurs in Grenville schists and gneisses that represent doubtless old sediments of the nature of silts and sandstones.

The pyrite deposits are usually described as veins, but they are really zones within the schists that have been impregnated with the sulphide without reference to secondary fractures or fissures. They seem to compare rather closely to the bedded structure of the wall rocks, whenever this is determinable, and consequently
assume a tabular or lenticular form in characteristic development. The sulphide is accompanied by more or less vitreous quartz and may be seen to occur in two forms: as finely divided particles rather evenly distributed through the gangue, and as aggregates of coarser particles and crystals in bunches, veinlets and stringers more irregular in their distribution. Some of the ore contains little else than fine granular pyrite in a gangue of quartz, feldspar, mica and chloritic alteration products. In other examples the ore is a network of small bands and stringers which intersect the gneiss or else consists of an alteration of the sulphide bands with layers of the rock, presenting a coarser appearance than the ore in which the pyrite is evenly disseminated and also as a rule containing a higher content of sulphur. The coarse ores carry 25 to 35 per cent, whereas the finer, disseminated variety is usually under 25 per cent in sulphur.

Some pyrrhotite may be present in the ores, not intermixed with pyrite generally but in separate aggregates that occupy a particular position, such as one or another of the walls of the orebody. Independent bodies of pyrrhotite are also found in the area. On the whole, however, it is much less common than pyrite. In sulphur content the pyrrhotite ores are practically on a parity with the others, notwithstanding the considerable difference in chemical proportions of sulphur and iron in the two minerals.

The deposits show marked persistence along their strike, and where they have been mined underground they have been found to persist in the direction of their dip or pitch as well. Their thickness, however, is small compared with the other dimensions. In most places they are not more than 15 to 20 feet thick from wall to wall, and 40 or 50 feet represents the very extreme, while they may be followed along the trend on the surface for several thousand feet and the ore zones are traceable for miles.

The pyrite deposits of the region have been described by A. F. Buddington\footnote{N. Y. State Defense Council Bul. 1. Albany, N. Y. 1917.} from whose report the following abbreviated account of the occurrences within the Gouverneur quadrangle has been in part compiled.

**Cole mine.** One of the more important pyrite occurrences is on the J. Frank Cole farm, 5 miles northeast of Gouverneur, close to the R., W. & O. railroad. It has been worked intermittently for the past 15 years, contributing a small output of lump ore, and has come into the hands of the New York Pyrites Company. A mill is
now (1919) in course of erection which will enable shipments to be made in the form of high-grade concentrates.

The shape of the ore bodies at this locality shows a marked departure from the simple form that characterizes most of the deposits in the district. Its precise structure, however, has not yet been fully determined. In the early operations two veins were encountered, on one of which the shaft was sunk 222 feet in 15 to 18 feet of ore with a northwest strike. On the hanging side, separated by 15 feet of schist, was another body which was followed for 90 feet in a northeast direction and for 60 feet at right angles thereto. It developed from later work that the vein in which the shaft is located and the overlying vein are connected on the northwest side by an ore band 10 feet thick. It seems probable that the ore has been subjected to compression and folding, but further developments must be awaited to determine whether this is actually the case. Recently a series of prospect pits put down between the mine and the highway showed the continuance of the pyrite to the east with a probable thickness of 30 feet.

The ore is conspicuously banded, showing alternate layers of coarse pyrite and fine pyrite admixed with schist. Some specimens are practically pure sulphides, and the average is well above the mean of most deposits. The lump ore as shipped contained 30 per cent or more sulphur.

Ore Bed School prospect. This is in the northeastern part of the quadrangle, 3 miles south-southeast of East De Kalb, town of Hermon. The ore occurs in a belt of rusty gneiss that extends northeast and probably connects with the Stella mines near Hermon village. Two veins are exposed on the hill one-fourth of a mile north of the school and have been prospected in a small way. They show ore of about the same quality as that of the Stella mines, but of uncertain thickness; the property would merit investigation if there was a market for material of this grade. Hematite was once mined in the vicinity, the deposit occurring in the same gneiss belt as the pyrite.

Farr prospect. This is situated in the town of De Kalb, 3 miles northeast of Bigelow, on the farm formerly owned by Alexander Farr and more recently by Henry Fleming. A vertical shaft was started in 1904 but was not continued to any considerable depth. About 6 feet of ore is shown in the shaft, mostly pyrrhotite, with a vein of pyrite on the east side. Another ore vein occurs to the west of the shaft, separated by 6 feet of gneiss, and is not well exposed.
There are evidences of folding, but the structure is uncertain. A prospect 50 yards north of the shaft shows 9 feet of pyrrhotite. The gneiss is bordered east and west by limestone and shows a width on the surface of 200 feet. Typical samples of the pyrrhotite ore contained 20.87 per cent sulphur and .22 per cent arsenic.

**Mitchell prospect.** This is located on the Calvin Mitchell farm, about 3 miles northeast of Bigelow, town of De Kalb. The ore zone, as shown in a prospect shaft, is 7 or 8 feet thick, consisting of pyrite with a band of pyrrhotite in the middle. The walls are injected Grenville gneiss. Samples gave about 24 per cent sulphur and .16 per cent arsenic.

**Styles prospect.** This is on the farm of D. G. Styles, 2 miles northeast of Bigelow. The vein is about 9 feet thick where exposed in the shaft opening, but contains intercalations of gneiss.

**Hendricks prospect.** In the town of De Kalb and 8½ miles southwest of Bigelow, near where the railroad crosses Boland creek is a vein that varies from 2 to 10 feet thick and is sheeted, so that the average is rather lean.

**Pleasant Valley School prospects.** A hill of rusty gneiss is a rather conspicuous landmark on the road from Edwards to Fuller-ville, just north of Pleasant Valley school. Some attention has been given to the uncovering of bands or veins of pyrrhotite that intersect the ridge and that average very high, in that mineral. The veins seem to be small.

**Kilburn prospect.** This prospect is in the belt of Grenville gneiss that borders the Sylvia lake limestone area on the north and west. There are no well-defined bands or veins and the ore consists mainly of disseminations of pyrite and pyrrhotite in fine grains, somewhat richer than the average of the country gneiss.

**References.**


Talc

Talc is perhaps the leading mineral product of the Gouverneur district. It has contributed directly about $18,000,000 in actual value since the beginning of production, and indirectly has been the means of introducing other industries for the utilization of the natural resources of the region, notably water power enterprises which are an essential factor in the economic production of ground talc.

The mining of talc has been in progress for more than 40 years—since 1880 without interruption. The total output may be placed in round numbers at 1,900,000 tons with a value that quite equals the figure above given. The product, which has special characteristics that make it indispensable in many manufacturing industries, finds a market all over the country, and under normal conditions in foreign lands as well. Although Gouverneur has given its name to the material as identifying the source or grade, the mining localities are several miles from the village in the towns of Fowler and Edwards. Gouverneur, however, is the general center for the management and operation of the mines and in early years was the shipping point. The Gouverneur and Edwards railroad now serves the district, being used to bring the talc from some of the mines to the mills for grinding and also for the shipment of the finished talc.

Nature and uses. Talc is a mineral of variable habits and qualities, and its uses vary with its characteristics. Chemically, it is all one and the same material—hydrated magnesium silicate. It occurs in two general forms: as a primary deposit from solution, and as a secondary product that results very commonly from local alteration of an anhydrous magnesium silicate, such as tremolite and enstatite. Primary talc has a scaly or foliated habit, like mica in appearance, has certain definite physical properties, and in chemical composition comes close to the proportions demanded by the formula, that is, silica 63.5 per cent, magnesia 31.7 per cent and water 4.8 per cent. Secondary talc has no well-defined physical structure but adopts the structure of the mineral from which it has originated, granular, fibrous or massive, as the case may be. It is likely to be somewhat impure, varying with the conditions, and particularly to contain unaltered remnants of the parent sub-
stances. When massive and coherent so that it may be quarried in blocks which are then wrought into various shapes, it is called soapstone.

The purer sorts of foliated, fibrous and granular talc are employed for grinding. Color, texture and degree of softness (freedom from grit) are the natural qualities of most importance. But to them must be added the degree of fineness produced in the grinding operation. For many purposes fine grinding is very essential. One of the main functions of the Gouverneur mineral—which is mostly of fibrous habit—has been as filler in paper manufacture, for which softness and pliancy are requisites. It is said to be retained by the pulp much better than clay, owing to its fibrous nature. The manufacture of rubber consumes large quantities. It is employed also in paints and distempers, as an ingredient of wallplasters, for electric and heat insulating materials, artificial stone, and many other purposes. There are few minerals that compare with talc in its manifold applications.

Occurrence. The productive talc area is defined by the belt of Grenville limestone in the southwestern corner of the map. The talc occurs in lenticular and sheetlike bodies, which are commonly referred to as veins, within the limestone belt from Sylvia lake to Edwards, a stretch of about 10 miles. The individual bodies conform in structural features with the limestone, having normally a northeast-southwest trend on the surface, but showing minor plications, crumplings and small faults that seldom are observable in the limestone. The dip of the deposits is to the northwest, between 30° and 60° generally, in some instances at still higher angles, varying from point to point with the rolls that appear in every mine.

A lenticular form is most common, although every variation from that type may be found. In thickness the bodies seldom exceed 30 or 40 feet in the widest part, measured from roof to footwall, while the horizontal length as indicated by the mine drifts may be 1000 feet or more. There is no known limit of the talc in depth; the deepest mines are 700 to 800 feet along the dip and no decided change in the deposits with regard to character of the material has been noted within that distance.

The talc bodies are distributed along the borders of the limestone and although they occur rather irregularly, most of the mines are grouped in two main belts extending northeast-southwest parallel with the limestone-gneiss contact. One of these lies on the north side of the limestone area in the vicinity of Taleville. It
contains the mines of the Uniform Fibrous Talc Company on the Oswegatchie river below Talcville, the old United States mine at Talcville, and the several openings of the International Pulp Company including nos. 2½, 3, 4, and 5 in the stretch between Talcville and the first mile northeast of that village. It is not uncommon to find two or more layers of the talc in overlapping arrangement in this section. The bodies are separated from each other by beds of unchanged tremolite or by limestone. In some instances the talc has both foot and hanging walls of tremolite schist, although more generally limestone forms one of the walls.

The second group of mines lies in the southwestern part of the limestone area and on the southern margin to the southeast of Sylvia lake. Here are the Balmat, White and Arnold mines, recently operated by the International Pulp Company, the mine formerly worked by the Ontario Talc Company near Fullerville, and also the shafts and prospects on the property of the Dominion Company just east of Sylvia lake. This belt is about 3 miles long and the talc occurs within a short distance of the footwall which consists of a dark amphibolitic rock injected by red granite. In this area there is more or less foliated talc associated with the fibrous variety, occurring in small seams which intersect the foliated talc or occupying more or less independent bodies.

Altogether there are nearly twenty mines and prospects in the district, but only a few of these have been actively worked in
recent years. Only the more important, including those under recent operation, will be described in this place.

**Talcville mines.** One of the principal producers in this section has been no. 2½ mine at Talcville, the property of the International Pulp Company. It is located on a seam of talc which lies on the north side of the limestone belt not far from the granite contact, the same seam that has been opened in the United States mine to the southeast, and probably has its continuation in nos. 3, 4 and 5 mines to the northeast of Talcville. The mine is opened by an inclined shaft which has now reached a depth of nearly 700 feet on the dip. The principal seam that has been exploited ranges from 4 or 5 feet to 30 feet in thickness. It starts on the surface with a dip of 45° to the northwest and steepens at the 600-foot level to 80° which dip is maintained to the bottom. On the hanging wall the talc is bordered by hard tremolite schist, within which there is more or less talc, and this in turn is succeeded by limestone. The body of talc shows numerous rolls and in places pinches down to a narrow seam; at the north end it swings around to the north owing to a fold and is practically squeezed out in that direction. The product of the mine is fibrous talc with practically no admixture with the foliated variety.

The outcrop of the talc body disappears a little distance to the northeast of the no. 2½ mine where the ridge is succeeded by an alluvial flat. Beyond this low ground the ledge reappears and is opened by the no. 3 shaft, a considerable producer of talc in former years. Next in order is no. 4 mine, one of the active properties of the International Pulp Company. This mine is also opened by an inclined shaft and has reached a depth of over 400 feet. The levels have an extreme length of 900 feet. Two parallel bodies of talc are exposed in this vicinity with a parting of tremolite schist. On the hanging side of the talc that has been worked by no. 4 shaft, is hard unaltered schist, then limestone and finally granite. On the footwall of the talc occurs a soft, clayey seam, a few inches wide, which is water soaked. No. 5 mine, next northeast of no. 4, marks the apparent limit of the talc in that direction. The mine has been closed down for several years and little is known about the underground workings.

Adjoining no. 2½ mine on the southwest is the mine formerly worked by the United States Talc Company which ceased operations in 1906. It is based on a continuation of the same seam, with conditions very similar to those described for the former mine.
The upper workings left by the operations previous to 1906 subsequently caved, rendering them inaccessible from the surface. The property recently has been acquired by the International Pulp Company and is being worked in conjunction with no. 2½ mine through drifts from this shaft below the caved area. It is one of the main sources of supply of that company.

The mine of the Uniform Fibrous Talc Company is situated a little southwest of Talcville along the east branch on a slight prominence known as Wintergreen hill. The main shaft, the one first opened, is close to the river. The company began operations in 1911 and the mine was practically a new development from the surface. On account of insecure conditions for mining the first shaft was abandoned after reaching a depth of 350 feet, and a second one was sunk on the hanging side about 200 feet distant. This tapped a new deposit by means of a cross-cut at the 130-foot level. The development of the second seam had not proceeded very far when the company ceased work, having lost its hydro-electric station at the Sullivan dam on the west branch through a washout. The last operations were in June 1921. The product was of good quality and amounted to 30 to 40 tons a day.

Sylvia lake district. The progress of mining in this part of the district has been retarded somewhat by the lack of shipping facilities, it being necessary to haul the lump talc several miles to reach the mills which are situated along the Oswegatchie river. The talc is of excellent quality, but differs from the general run in the northeastern section in having a greater proportion of scaly mineral. The two kinds are so segregated, however, that the grade of the mill product can be controlled. The foliated talc yields a very soft product, which when finely ground commands a special market.

The Balmat mine is in the extreme southwest end of the district as at present developed, about one-half mile east of Sylvia lake. It is on the road running from Fowler to Balmat Corners, with Emeryville on the Gouverneur-Edwards railroad as the nearest shipping point. The mine has been worked through an incline which starts at an angle of 27° but steepens toward the bottom. The main levels extend about 1000 feet on the course of the deposit, northeast-southwest, and the talc measures 30 to 40 feet from wall to wall in the widest part. On the hanging side of the seam occurs a band of from 6 inches to 3 feet of foliated talc, clear white and free of impurities, the rest being the fibrous variety pseudomorphic
after tremolite. The mine is one of the main sources of rock for the International Pulp Company which hauls the output to Hailesboro for grinding.

The Dominion Company owns deposits, not at present mined, on the north and west sides of the Belmat next to the lake. Some development work has been done on them but active mining must await the construction of a mill to handle the output.

The Wight mine is northeast of the Belmat and about one and one-half mile south of Fowler. Its output is handled by the International Pulp Company.

The Arnold mine, a little northeast of the latter, is one of the old Union Talc Company’s properties and was taken over by the International Pulp Company when that company went out of business. It is now owned by the W. H. Loomis Talc Corporation, having been acquired in 1919 and since operated by this company for supply of its new mill at Emeryville. It is opened to a depth of 300 feet with levels that extend about 500 feet along the axis of the seam. Like the other deposits of this section, it contains both fibrous and foliated grades, with some long-fibered material. It is likely to prove one of the largest producers in the district under the new management which has plans under way for a large increase in its milling operations.

Fullerville. There are several prospects in this vicinity and one mine, now inactive, that has been quite extensively worked, the property of the former Ontario Talc Company. This is located about 1 mile below Fullerville beside the west branch. The deposit is probably not connected with either the Talcville or the Sylvia lake areas, being separated from the former by about 2 miles of limestone in which there are no developed bodies, and from the Sylvia lake region by an unbroken mass of amphibolite. The mine was last worked in 1917, in which year the mill at Fullerville of the Ontario Talc Company was burned. At that time the deposit was opened by three levels reached through a slope driven at about 45° angle following the dip. The talc measured from 12 to 18 feet between walls, not including offshoots into the hanging which in places increased the working thickness. The rock consisted mostly of short fiber, with a little admixture of foliated and longer fiber. The company produced about 20 tons a day of ground talc.

Milling of talc. Mills for reducing the talc to a pulverized condition have been built at various places along the Oswegatchie river from Talcville and Fullerville to Hailesboro 3 miles east of Gouver-
Their location was determined usually by local water powers. In recent years transmission lines have made possible the centralizing of milling operations at more advantageous points and there are fewer plants now than formerly.

The methods employed in the reduction process have changed much in late years and innovations are still being made. While talc is one of the softest of minerals, its comminution to the state of fineness demanded by most trades is a laborious if not a difficult operation, in which opportunity is given for constant improvement. The present system or systems represents a gradual development extending over the whole period of the industry. The earliest method consisted in grinding in buhrstones similar to those used in flour mills, but now the reduction is accomplished in several stages by special types of machines, each adapted to the particular operation for which it is used.

Until a few years ago the common mill equipment consisted of a crusher for breaking the mine rock, followed by an intermediate crusher, from which the product went to a revolving drum or conical mill, and then to a cylinder where the final reduction was accomplished. The latter was usually the Alsing cylinder, with Danish pebbles for grinding medium, and the talc was retained in the cylinder until the desired degree of fineness was reached. This represents the so-called batch process. It has the disadvantage of not being continuous in operation. A later development consisted in the replacement of the cylinders by long tube mills with continuous discharge. In one of the largest mills the material is taken directly from the crusher into such a tube mill, the discharge going to a second mill, this to a third, and the final reduction made in a fourth mill, the flow being continuous from one to the other.

Along with improvement in grinding has come an increasing demand for the finest sizes of ground talc. At one time the general run of product ranged from 100-mesh to about 200-mesh, the latter being about the minimum limit reached in grinding. Much of the demand now calls for 300-mesh material or finer. This has necessitated the incorporation of additional equipment for sizing the talc which formerly was carried out by screens and bolts. About the only practical means of doing it is by air flotation. In the latest designed mills each stage of reduction is accompanied by air separation so as to by-pass the fine material from the succeeding steps and to provide uniform sizing for the whole product. This has been the greatest advance of the milling process reported in
recent years, as it enables a greater output to be made by the same crushing equipment and tends toward an improved product. The air separator effects the removal of much of the hard particles, quartz and mill grit, which have been something of a handicap to the use hitherto of the talc from this district for certain purposes.

A distinct grade of Gouverneur talc is buhrstock, made from the selected fibrous rock by omitting the final reduction, the process being carried only so far as to give a thoroughly shredded material of the texture of short-fiber asbestos. It has been made in restricted quantities of late years, although once a regular product of the mills. Its uses were mainly in insulating materials and prepared plasters.


Feldspar

The abundant development of pegmatite in connection with the main granite intrusions of the district has already been commented on in the description of the geological features of the area. The occurrences individually are seldom of large extent, but they are widely scattered and not infrequently follow in close sequence so that they constitute a rather important element of the physical structure when taken in their entirety. They exhibit a good deal of variation in their make-up, particularly with reference to the feldspar. This may be one of several species and the proportions may range from nearly solid feldspar aggregates to those in which the mineral is quite subordinate to the quartz. Dark silicates usually are of little importance, although black tourmaline is a persistent and occasionally a prominent ingredient. In most of the pegmatites examined the feldspar has proved to be microcline or an intergrowth of microcline with albite, but an acid plagioclase of the type of oligoclase is not uncommon as a minor component. The color of the microcline ranges from pure white to creamy white, occasionally being pink or red. The plagioclase is white or greenish; the quartz
is usually milky white. Mica and hornblende are dark ingredients additional to tourmaline.

Within the limits of the map the principal occurrence for the production of pottery spar is on the Kilburn farm, town of De Kalb, between Bigelow and De Kalb Junction. It has been worked for several years by the Green Hill Mining Company, Inc., with office at Gouverneur. The feldspar is white microcline intergrown with albite, occurring in well-segregated crystals that measure from 5 or 6 inches to 3 feet long. Iron is practically absent, in which respect the product is superior to most of the material on the market. The pegmatite body has the shape of a lens with the major axis running northeast-southwest and a steep or nearly vertical dip. The workings consist of both open and underground quarries. There is little waste and this mostly quartz which is removed by hand cobbing. The lump spar is hauled to De Kalb Junction for shipment and is sold to grinders at Trenton, N. J. and other points for use in pottery.

In view of the increasing scarcity of high-grade spar in the eastern markets, systematic prospecting within Gouverneur and surrounding districts would seem to be well worth while. The porphyritic granite of this region shows a well marked tendency to develop pegmatite phases and its usual low iron content is favorable to the occurrence of spar with a minimum admixture of the dark silicates that are the bane of most quarries.


QUARRY STONES

The quarry stones available for use within the area are limestone, granite, and various gneisses that range from light granitic rocks to dark gabbroic varieties. Potsdam sandstone outcrops in several places, but the ledges are usually small, scarcely substantial enough to form the basis for systematic quarry operations like those carried on around Potsdam in northern St Lawrence county.

Limestone and Marble

The crystalline limestones of the Grenville belts are sources of building and monumental stone, furnace flux, crushed stone and stone for lime burning. The purer, more substantial beds have been quarried extensively for structural stone, examples of which are
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to be found in many of the churches and public buildings of northern New York and in other parts of the State, and also for polished work or marble of which the Gouverneur marble is a good example. The principal quarries are located along the Gouverneur-Richville belt and most of them in the vicinity of Gouverneur.

The limestone in general is medium to coarse crystalline and white or light gray in color, but sometimes is a dark blue shade as in one or two of the Gouverneur quarries. It is normally a calcite limestone with a varying, although small, percentage of magnesia. The carbonates amount to about 95 per cent of the whole mass, so that it ranks as one of the purer limestones to be found in the State. In a few places the magnesia increases to such proportion that the rock may be characterized as a dolomite. The change from calcite limestone to dolomite takes place abruptly, but whether it reflects an original variation in conditions of deposition or is due to a secondary process after the strata were laid down, is not clear. In the former case it would be expected that the variation should be related to the bedded structure, but such relation can not be definitely established. The occurrence of dolomite is quite local and unimportant as compared to the main body of calcite limestone.

The Gouverneur marble is quarried from a small area southwest of that town. The quarries, with few exceptions, lie along a narrow belt which extends for over a mile in a northeast-southwest direction. They lie on the outcrop of the "vein" or bed which dips northwest at an angle ranging from 15° to 30° on the northeast end to 80° to 90° in the southwesterly quarries. The vein has a pitch that is toward the southwest at an angle of 20° or 25°. In color it is a mottled white and grayish blue, or light and dark blue stone, running occasionally to an almost solid dark blue, which is the tint most sought for. In the lighter mottled sorts, the grain is coarse, with the lighter and darker particles segregated more or less into separate areas. The individual calcite particles mostly have a diameter of 1 to 2 mm. In the dark blue marble the grain is much finer, the calcite averaging only a fraction of a millimeter. The bluish color seems to be traceable to the presence of graphitic carbon in very small submicroscopic particles. Free carbon has been detected in chemical analysis of the stone, but in too small amounts to be separately weighed. That the variation of color conforms more or less closely to the bedding is evident from a study of the relations revealed in the different quarries. The lighter colors are found in the higher beds of the northern section, and
the dark blue marble is found in the lower beds of the southwest. This relation has been established clearly by results of drilling.

The limestone from the Gouverneur area is susceptible to high polish, which together with its attractive luster and good texture has given it considerable favor as a monumental stone. For building purposes it is mainly used in rock face ashlar, of which the color is a medium gray; on cut or hammered surfaces the color is considerably lighter.

Among the quarries in the Gouverneur district that have yielded building and monumental marble are those of the Gouverneur Marble Company, the St Lawrence Marble Quarries, the Northern New York Marble Company, and the Callahan quarry, all situated in the area from 1 to 2 miles southwest of Gouverneur. In the past few years the principal producer has been the Gouverneur Marble Company. A mile distant from the main group of quarries is the Rylestone quarry on a low ridge nearly due west of Gouverneur and south of Natural Dam. The quarry site is just off the limits of the Gouverneur sheet. The marble is bluish gray with a mixture of white and blue calcite. It is owned by J. J. Sullivan of Gouverneur.

A white dolomite has been quarried for building stone in the vicinity of Peabody Bridge, 2 miles north of Gouverneur. The stone has a coarse texture and is clear white. Analysis indicates a nearly pure dolomite. It was once worked by the White Crystal Marble Company and has been operated in a small way by J. J. Sullivan.

In the vicinity of Richville are many limestone quarries which have been worked at one time or another in connection with lime-burning plants, also for crushed stone and furnace flux. One of the larger quarries is about 2 miles south of Richville station close to the R. W. & O. railroad tracks. It was operated for a number of years by Corrigan, McKinney and Company.

White dolomitic marble occurs also in the town of Fowler; extensive exposures are found on the Abbott farm just west of the Fowler post office. It has been worked in a small way principally for making artificial building stone.
Analyses of Gouverneur Marbles

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1 Sample from the extra dark quarries of the St Lawrence Marble Quarries. R. W. Jones, analyst.
3 Rylestone Quarry. R. W. Jones, analyst.
4 Northern New York quarry.
5 Dolomite near Peabody Bridge.

Granite and gneiss. The common granites of the area have a red or pinkish color and are composed of feldspar, quartz and some dark silicates like hornblende and biotite. They are developed over extensive areas but only in a few places are they unmixed with Grenville rocks, so that usually they are not well adapted for architectural stone. They afford, however, a wealth of material suitable for road making and foundation purposes. The same is true of the gneisses, some of which are merely granite-injected members of the Grenville schist series, variable in habit and durability, but as a rule substantial enough for all ordinary purposes. The amphibolites afford a dark stone that is especially serviceable as crushed stone for road making on account of their tough well-knit character, a feature imparted by the abundance of hornblende.

No permanent quarries have been opened in the granites and gneisses within the Gouverneur or surrounding area. Road improvement has called for a considerable production of crushed granite, but as the requirements could be supplied usually from sites close at hand operations have nowhere been carried on on a large scale.

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TWENTIETH REPORT OF THE DIRECTOR OF
THE STATE MUSEUM AND SCIENCE
DEPARTMENT

INCLUDING THE SEVENTY-SEVENTH REPORT OF THE STATE MUSEUM,
THE FORTY-THIRD REPORT OF THE STATE GEOLOGIST AND THE
REPORT OF THE STATE PALEONTOLOGIST FOR 1924

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ALBANY
THE UNIVERSITY OF THE STATE OF NEW YORK
1925
THE UNIVERSITY OF THE STATE OF NEW YORK
Regents of the University
With years when terms expire

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1936 Adelbert Moot LL.D., Vice Chancellor - - Buffalo
1927 Albert Vander Veer M.D., M.A., Ph.D., LL.D. Albany
1937 Charles B. Alexander M.A., LL.B., LL.D., Litt. D. - - - - - - - Tuxedo
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The University of the State of New York
The State Museum, January 28, 1925

The Honorable Frank P. Graves
President of the University

Sir: I beg to submit herewith my report as Director of the State Museum for the year 1924.

Very respectfully
John M. Clarke
Director

Dr John M. Clarke, State Geologist and Paleontologist, and Director of the State Museum and Science Department of The University of the State of New York, died on May 29, 1925, just prior to the publication of this report. At this time it is not possible to recount the irreparable loss to the State and to the world of science caused by the death of this distinguished scholar but a full statement of Doctor Clarke’s 40 years of service to the State and his contributions to science during that period will be given in the next report of the State Museum.

Frank Pierrepont Graves
Commissioner of Education and President of The University of the State of New York
TWENTIETH REPORT OF THE DIRECTOR OF THE STATE MUSEUM AND SCIENCE DEPARTMENT


GENERAL. Lack of space is the most outstanding obstacle to the progress of the Museum exhibitions. The consciousness of it pervades all operations which might otherwise be planned for the more effective presentation of the educational exhibits. Having utilized all available floor space, it has been necessary to creep down the stairways and an extension of the exhibit in paleobotany has been installed on the western stairway and includes the first landing on the level below. It is known as the Subgallery of Paleobotany. The large and elaborate paleobotanical group representing the Gilboa Fossil Trees in their natural habitat has now been brought practically to a close after 2 years of laborious and ingenious work. It is believed that this will prove an effective and highly educative display. It certainly has the merit of being an approximate representation of the conditions under which these great trees grew and ought to afford a pleasing picture of these earliest forests known to have existed in the history of the world. This group includes about twenty of the fossil stumps from Gilboa as a part of the foreground, the background being a mural representation of a coastal marsh, in which it is believed the trees grew. In the middle distance are restorations of the trees with their leafage and fruit as they have been made out from prolonged and most careful study of the remains as found after much search in the rocks around Gilboa. The floor
space in front of this tree group will be assigned to other specimens from this ancient forest, and in the center of the floor arrangement is located a particularly large and fine slab which shows the base of one of these trees of smaller size with the roots radiating from its edge in all directions and to a distance of 2 or 3 feet. This is the best exemplification found of the mode of anchorage of the trees in the soft muds in which they grew. In all the elaborate contrivances necessary to the effective presentation of this tree group, in respect to adjustment of lights and installation of various appurtenances, the Director acknowledges the very effective help of the Chief Engineer Edward R. Lord, and his staff.

Unexhibited collections. There remain stored away in various places in the Education Building important collections of material which can not be shown for lack of Museum space. Among these are the entire collections of the recent mollusca of New York and elsewhere, and it is a matter of constant regret that these collections can not be shown, in as much as the study of the mollusca has always interested a considerable number of persons, and it is not proper to restrain such interests by hiding away material which ought to be made accessible to such students.

Parks. The administration of the affairs of the Museum parks as now constituted by statute, comes under the control of the State Council of Parks. This has been a helpful procedure in so far as it has given means for repairs and upkeep which were not before available, and there is good reason to hope that hereafter something like adequate compensation may be afforded to the custodians at the Clark Reservation and at the Chittenango Falls Park. The Museum reservations are thus in better condition, so far as convenience to the public is concerned, than they have been since their acquisition. What is to be the eventual fate of these properties under the new legislation is still uncertain. In the case of several of them, the Clark Reservation, the Stark’s Knob, and Cryptozoon Ledge, the titles lie in The University of the State of New York, and in one of these title deeds the condition is made that in case supervision by the State Museum is surrendered, the property shall revert to the original donor or to his estate. Legislation which will probably be formulated during the coming legislative session, will undoubtedly make some provision for general administration of such natural monuments through the State Council of Parks. No further acquisitions have been made. The Legislature of last year favored the acquirement of the archeological property known as the Flint Mine Hill, an aboriginal flint quarry, but although the bill
for the transfer of this property to the State Museum passed the Legislature, it was allowed to lapse by the Governor in the expectation that it would be taken up by the State Council of Parks. So far, however, the council has not signified its approval of this transfer. The program of the State Council of Parks is actuated largely by the recreational sentiment which has been so effectively encouraged by the President of the United States and thus keeps in the foreground the recreational needs of the masses of the people, especially in the surcharged municipal districts of the State. It has shown itself very likely to overlook or disregard matters of moment in the reservation of natural monuments of high educative interests which should be preserved against the inroads of industry and population. The State Council of Parks as at present constituted under the statute, is made up of representatives of the large park interests, each of whom has direct concern only in the park or parks under his official charge, and in such a board it is quite difficult to arouse any degree of interest in concerns which are outside the active official affairs of the individual members.

Museum Association. This association is the expression of a desire on the part of the Museum to be helpful to all citizens who are interested in any of the sciences here cultivated. Its membership has now grown to be about 8,000. The form of the circular sent out is as follows:
NEW YORK STATE MUSEUM ASSOCIATION

Organized 1910

You are invited to become a member of the New York State Museum Association. Membership in the association has neither dues nor assessments and carries no personal obligation.

Object. The object of the association is to bring into closer relationship with the State Museum all citizens of New York State who are interested in such scientific and other subjects as are included within the scope of this museum.

Service. The State Museum, through its staff of scientific experts, is ready at any time to give information to those who are interested in the subjects mentioned below and to suggest courses of reading or study in these lines. To those who are making collections in natural history, information as to procedure and as to the location of suitable sites for collecting such material will readily be given.

Membership. To become a member

a Sign and return this circular.
b Check the numbered subjects in which you are most interested.

SUBJECTS

Geology
1 Geology in general
2 Economic geology
3 Structural geology
4 Glacial geology
5 Paleontology or the study and collection of fossils

Botany
6 Botany in general
7 Wild flowers of New York State
8 Ferns and mosses
9 Mushrooms
10 Trees and forests
11 Plant diseases
12 Swamps

Entomology
13 Entomology in general
14 Insects injurious to agriculture, horticulture and forests

Zoology
15 Zoology in general
16 Birds of New York State
17 Large and small mammals
18 Reptiles
19 Fishes
20 Conservation of animal and bird life

Archeology
21 Archeology in general
22 History of the New York State Indians
23 Sites of Indian culture in New York

After checking this sheet in accordance with your wishes, sign here, giving full address

Name ....................................................
Street ..........................................................
City or village .............................................
Publications. During the past year the following publications have been issued:


Miscellaneous: Guides to the Mineral Collections, Circular of Information, etc.

Of the foregoing publications, The Geological History of New York is a second edition, the public demand for it having required a reprinting of the book. The Memoir on The Devonian Crinoids is one of the series of quarto volumes on the paleontology of the State and this has excited widespread interest in scientific circles both in America and other countries. It has received the most flattering notices in scientific reviews and elicited highly favorable comment on the general work which the Museum is and has been for more than 50 years carrying on in the line of paleontological investigations.

Legislative support and loss of staff. The financial provision made for the support of the State Museum is 1/372 of a mill on each dollar of the assessed valuation of state property, and about ½ of a mill on each dollar of the tax income of the State. This brief analysis is in itself sufficient to explain the reason why the expert members of the State Museum staff are constantly leaving their positions in search of something that will guarantee a reasonable return for their services. There has been in recent years a constant exodus of the best talent from this service into other places. This certainly does not stand to the credit of the legislative body which seems to view the proceeding with entire indifference and with a very much lessened comprehension of the value of such service to the State than their predecessors in office entertained. Things are done better than this in countries where the intellectual life is more magnified and honored.

GEOLOGY

Rock deformations. In the large field of geology as applied to the problems of New York, active operations have been carried on, especially in the region of the Schunemunk mountains and over the area covered by the Schunemunk quadrangle on the topo-
graphic map. This is an area of the most complicated structure although in a large degree buried from sight. Final reports on this work will show that through this southeast zone of rocks in this State the dislocations concomitant with the mountain-making have broken and crumpled the crust of the earth in a manner that seems most extraordinary to a student of New York geological structures. It is apparently a continuation of the extreme deformations that are recorded in the rocks at Rondout and Kingston where there have been complete overturns of the rock strata so that older rocks are found resting upon those of later date.

Mountain-making. The problem of the making of the mountains of New York is one of growing interest and of fundamental importance of the science of geology. The observations made by Dr. Rudolf Ruedemann, on the mountain folds of the basal rock mantle of the entire earth, the result of arduous and searching records from observers in all parts of the world, bring out very clearly the fact that the first mountains of the earth, that is, the fundamental lineaments of the earth’s crust turned up by the radial contraction of our planet, have really been the parent mountains of the major mountain systems existing today. Doctor Ruedemann has found from his careful studies that the worn off and in large measure concealed edges of the crystalline basal rocks known generally under the term of Precambrian rocks, have a well-defined trend of structure or trend of bedding which is a clue to the axes of their folding. These mountain lines or lines of weakness having once given way to tangential stresses, have generally speaking, established themselves as lines of mountain-making for all subsequent time. As an illustration, the basal mountain structures in eastern New York, although worn down to their roots, are the floor on which the Taconic and Appalachian mountains have been built, and they seem likewise to have furnished the directives and courses for these later mountains; in other words, we are entitled to speak of mountain ranges generally which have been so obviously guided by the fundamental mountain folds, as “posthumous mountains.” Doctor Ruedemann’s original discussions of this problem of fundamental geological importance have been published in these reports. The present report contains an application of these conclusions to the structure and physiography of North America.

Earth movements in New York. One can not speak of the probability of crustal dislocations in the eastern United States without opening himself to the implication of being an alarmist. However authoritative the records for such dislocations may be, the public
does not care to be reminded of them, and intimations that even in this region of most ancient rocks we are living on an uneasy crust are received with detachment and stony silence. Nevertheless the facts remain. The State Geologist has on various public occasions called attention to the records of earth movements in this vicinity, some of which have been destructive. If any earth movement at any time in our recorded history has been sufficiently violent to cause extensive disorder of the land, such a movement may recur. Every resident of eastern New York is aware of occasional shudderings of the crust causing rattling of china, swaying of pictures, and such minor evidences of uneasiness. We do not yet know just what record such movements make on the rocks of the earth, but it is quite evident that although they occur at rather remote intervals and are in themselves, from the human point of view, merely interesting sensations, they always imply the possibility of greater disturbances. The public hostility toward the recognition of a menace in these earth movements is due to two causes: firstly, the fact that no living being has been a witness of any damage to property or life in this part of the country from such causes; secondly, that vested interests dependent upon the security of the land must decline to take notice of any such menace. For the first reason we must set against it the geologist’s point of view. There is a positive record of destructive earth movements in the zone of fault which lies along the course of the St Lawrence river and runs south from Montreal in the line of the Lake Champlain and the upper Hudson valley. The record is not of the most dependable character, but the earthquake of 1663, stories of which in the relations of the Jesuit and other institutions established along these lines at that time, even after proper subtraction has been made for the emotions of the writers, do not fail to indicate the possibilities of these displacements of the rock foundations. In the southern Hudson river valley the lines of displacement have followed the course of the structure lines of the basal Precambrian rocks, but the entire zone of the Hudson valley is one that records extensive rock displacements in the past which may be renewed at any time when the subterranean stresses have piled up to a peak where their relief becomes imperative. The attitude of the general public toward matters of this kind is reflected by the absence of reaction from a highly sensational, almost lurid account of earthquake possibilities in southeastern New York, which recently appeared in one of the prominent monthly magazines. The author of this article was a vulcanologist of high repute, and the obvious purpose of his distressing picture was to inaugurate in this eastern country
an institution for the exact measurement of earth stresses and strains, the constant subterranean tilts and movements of the rocks that we know to be going on beneath us. This rather extravagant and certainly intensive argument was received by the press of New York and the East in almost absolute silence. Recently a geologist of distinction with an engineer's experience gave a carefully compiled account of the earthquake dislocations in and around Boston. The dissertation was prepared for the benefit of Boston engineers and architects. The writer of it brought together from historical records a formidable number of these displacements. So far as known, however, this paper did not bring any reaction from the press or from the public and indicated the importance of taking precautionary measures for future construction and self-preservation. Six months after the appearance of this Boston paper, an earthquake of some magnitude occurred in that region along the line of the so-called Fundian fault which runs thence northward into the Bay of Fundy.

At various points in eastern New York are surface evidences of continuing and present displacements of the rock beds. Some of these have been recorded in the reports of this survey where the breaking down of the rocks for little distances has actually faulted the overlying burden of soil and drift. There is a place in the Helderberg mountains, not far from the Indian Ladder, where a surface of rock smoothed off and polished by the glaciers has been faulted down in a series of small steps, showing that these movements have proceeded since the close of the glacial period. In speaking of these light displacements it is necessary to bear in mind the fact that an earthquake shock of devastating violence is not due so much to the distance the rocks move, as to the mass of the rock moved and a large mass of rock moving but a short distance downward, horizontally or upward, is the usual cause of serious disaster.

The point of these remarks is this: New York State is involved in an eventual risk and a perpetual menace. Neither New York State nor any part of the eastern United States is giving any adequate attention to the importance of acquiring dependable information as to what these earth movements may mean to the safety and security of the people. While there is no occasion to become excited over possibilities of this kind, and while it might be unwise to make these matters the subject of open and popular discussion lest distortion of expression should occur and needless excitement be aroused, it is nevertheless true that until the State of New York establishes a geophysical institution equipped with apparatus of the
most accurate precision for registering these earth movements and estimating their periods of recurrence, it will not be doing its full duty toward the State and its prodigious invested interests. The study of seismology has now gone so far that it has become well nigh possible to forecast the next occurrence of destructive earthquake shocks in regions which are today possibly subject to them. Omori, the distinguished Japanese seismologist, forecast the last Japanese earthquake which caused the death of nearly a half million people. Prophets of evil have never been popular. We have a press story to the effect that a Japanese seismologist who more recently prophesied a recurrence of the Japanese disturbances was almost murdered by the mob. The writer of this report has a personal acquaintance with a geologist who was threatened with tar-and-feathers after an address before a chamber of commerce on the possibilities of such crustal disturbances in this State.

The outstanding fact is that, as above intimated, the State of New York can meet this full duty in this matter only by acquiring, through its proper officials, an intimate knowledge of earth movements which will help to afford it a greater security.

The problem of the salt. New York State has plenty of salt. It has produced salt for a century and the outstanding problem connected with it is and always has been to insure a market. More than ever we begin to see that the quality of the market depends upon the quality of the salt and the particular and intimate composition of our salt beds. It would be rehearsing well-known facts to recur to the mode in which the salt is stored in our rocks.

As the driller finds it, it appears in one or several beds, interbedded with the rock strata and having a uniform chemical composition. The area of these subterranean salt beds extends from well east of Syracuse on to the western border of the State, and the same deposits are more or less continuous into Ontario and Michigan. It has been the historic interpretation of the salt deposits that they were laid down at a period of our geographical development when the coast line of the continent approximately skirted the region where now lies Lake Ontario, then bending off broadly along the course of the present Mohawk river, turning at the inner corner of the Appalachian land and running thence southwesterly. It was a shelving shore bounded outside by some broad sand barrier or bar, which created great salt pans where, by solar evaporation, the salt waters were progressively intensified in their salinity until precipitation of the salts began, and that when the peak or climax of precipitation was reached, a gentle lowering of the coast line allowed
the normal marine waters to enter this extensive area and diminished
the salinity as gradually as it had increased, until finally normal
conditions of deposition were restored throughout the entire extent
of this coastal region.

This assumed process would be the simple, normal result of the
rise and fall of the land under such geographical conditions as
have been outlined. In any such process as this, normal deposition
of the salts held in solution by the sea would have been in inverse
order to the solubility of such saline contents. The more insoluble
salts would come down first and the first deposit, therefore, in such
an evaporating pan would be the sulphate of lime, gypsum, followed
by chlorides of magnesium, carbonates of magnesium, chlorides of
potassium, magnesium etc., and at the peak or climax the chloride
of sodium, or salt. This process would be inverted with the incom¬
ing of normal sea water, which would help to increase the solubility
of the various minerals so that the last as well as the first deposit
in this cycle would be gypsum. That is to say, in a section across
the salt beds there should be at the bottom, below the beds of salt,
gypsum, and above the beds of salt also deposits of gypsum, and
in the intervening beds not merely salt itself, but some intermixture
of the chlorides of sodium with potassium, etc. This is the usual
occurrence in most of the large salt deposits of the world that have
been formed by such process of evaporation, and salts of this kind
which show accumulation by normal evaporation processes are to be
designated as primary salt.

In the past we have rather assumed that the accumulation of our
New York salts was by such processes, and that in their time the
coast line was fringed by such salt pans. The intimate study of our
salt beds, however, seems to throw increasing doubt upon this mode
of their accumulation. There are no gypsum beds immediately
underlying the New York salts. All of the large amount of gypsum
recorded comes from beds above the salt.

Untiring and incessant efforts have been made to find a potash
element in our salt beds. A large number of analyses has been made
of the salts and brines from every part of the salt field in the hope
of determining the presence of potash. These analyses have never
provided more than a mere trace of potash. The inference, there¬
fore, from this accumulating evidence is that there has been some¬
thing abnormal in the deposition of the New York salt beds. It is
not conceivable that by the simple process of solar evaporation salt
beds could accumulate without the presence of the salts of potash,
and we are therefore forced to the conclusion that the potash once
present in connection with these sodium deposits must have been removed by some process and perhaps deposited elsewhere. This fact, taken in connection with the irregularity of the gypsum deposits, has raised grave doubt as to whether the New York salt beds can be regarded as primary salts; whether they may not be a secondary deposition of salt derived from some previously deposited bed of normal salts, probably lying off to the north and deposited by a process of leaching, which has concentrated the sodium salts in their present position while the more soluble potash salts have been carried off into some other latitude at the same horizon, and may be today deeply buried under a heavy overburden along the more southerly continuation of the beds of the saline formation.

Professor H. L. Alling, who has been deeply concerned with the character of our salt and the problem of the salt beds, reports finding in the salt itself strings of black bituminous matter which would seem to indicate the presence of some form of plant life, possibly comparable to the algae which are known to occur in normal salt beds and have been specially reported from the beds at Malagash, Nova Scotia.

It can be readily understood how a low coast with its chain of lagoons would be a receptive and suitable place for such secondary accumulation as seems to have occurred and our present suggestion as to this form of accumulation does not necessitate any essential change in the interpretations. The investigation at present under way will help to prove or disprove these suggestions.

The Cobleskill coral reefs and the Bertie lagoon. Closely knit up with the foregoing are interesting determinations which have recently been made in the investigations by Doctor Ruedemann. In the generally accepted geological column of New York rocks, the Bertie waterlime has been regarded as the upper stage of the salt-bearing group or as it is designated in accepted usage, the Cayugan group, while the Cobleskill magnesian limestone or dolomite is looked upon as a later and the next succeeding stage.

The Cobleskill extends from eastern New York to Buffalo. The rock is obviously a mass of corals. There are many places where these corals have been so digested and altered that their individual structure does not appear, but the dolomitic character of the formation is a rather definite clue to its origin as coral reef. The interpretation of this limestone comes to be in geographical terms a barrier reef extending along the entire coast line of New York from east to west, very much as the great Australian reef fronts the eastern coast of Australia today. Behind this reef were lagoons in
which the Bertie waterlime was deposited. These rock beds are most fully developed from the vicinity of Utica westward, and in them the remarkable fauna of Eurypterids, the most impressive in the world, is preserved. Along with these occur a series of notable, hitherto mostly undescribed, marine fossils which Doctor Ruedemann has worked out in great detail.

Indeed, this assemblage makes a singularly interesting faunal unit, which it is hoped will soon be elucidated in our publications. Doctor Ruedemann’s very great skill in bringing out the extraordinary characters of this fauna has served to make the most effective use of haphazard objects which have never before been properly appreciated. As a result of these investigations it is Doctor Ruedemann’s conclusion that the Cobleskill coral reef and the Bertie lagoons were contemporary and in some degree intermixed.

INDUSTRIAL GEOLOGY

C. A. Hartnagel, Assistant State Geologist

The completion of statistics on the mineral production of New York State for the year 1923 marks the twentieth year since this work was undertaken by the State Survey in 1904. The annual value of the mineral products of the State has shown a steady growth from 1904, in which year the minerals produced had a value of over $28,000,000. During the past 4 years the value of the mineral products has averaged well over $70,000,000 annually.

Clay materials. In 1904 the value of clay materials produced in the State including various types of brick, terra cotta, pottery, and tile, amounted to over $11,000,000. The 1923 production of the same materials was valued at over $25,000,000.

Portland cement. In 1904, 1,377,000 barrels of Portland cement were produced with a value of $1,245,000. In 1923 there was produced 6,853,000 barrels with a value of $12,834,000.

Natural cement. In 1904 the number of barrels of natural cement produced in the State was 1,881,000 and in number of barrels exceeded the production of Portland cement for that year. At present the output of natural cement has declined until only a few thousand barrels are produced annually, this by only a single producer.

Gypsum. The mine output of gypsum in 1904 was 151,455 tons with a value of $424,975. The 1923 output was 1,361,116 tons with a value of $10,344,745. The total output since 1904 is over 10,000,000 tons with a value of over $50,000,000.
Garnet. The output of garnet in 1904 was 3045 tons with a value of $104,325. The 1923 production was 7662 tons valued at $583,190. New industrial uses for garnet indicate an increase mine output of this material.

Iron ore. The output of iron ore since the year 1904 has fluctuated considerably. In 1904, 618,000 tons of ore were produced. The 1923 production amounted to 734,000 tons. Six different years during this period the annual production has amounted to over 1,000,000 tons. The total production for the 20 years is over 17,000,000 tons, of which the magnetite produced amounted to over 16,000,000 tons.

Salt. The salt produced in 1904 amounted to 8,724,000 barrels with a value of $2,102,000. The 1923 production was 14,756,000 barrels with a value of $7,403,000.

Stone. The value of the production of stone including granite, limestone, marble, sandstone and trap in 1904 amounted to $5,169,000. The 1923 production of the same materials was $10,648,000. The increase in value is due entirely to limestone which has shown an increase since 1904 of over $6,000,000. Each of the other items included under stone has shown a slight decrease in value of production.

Slate. The value of slate produced in 1904 amounted to $93,000. This value represented largely roofing slate which at present has a decreased output of only about two-thirds of the amount produced 20 years ago. With the present large output of slate granules which became an important factor in the slate industry about 1918, there has been a great increase in the value of products credited to slate and the 1923 output largely representing granules was $927,000.

Talc. The production of talc during the past 20 years has averaged around 66,000 tons annually. In 1904 the production was 65,000 tons and in 1923, 71,000 tons. At present prices the annual production is valued at well over $1,000,000.

Natural gas. The production of natural gas in 1904 was 2,399,000M cubic feet. In 1923 the production was 6,497,000M cubic feet. The largest production was between the years 1913 and 1920 with an average annual production of 8,000,000M cubic feet.

Petroleum. The production of petroleum in 1904 was 1,036,179 barrels. In 1912 the production had declined to 782,661 barrels. Since 1916 there has been a gradual increase in production and the 1923 output is 1,250,000 barrels, the largest output since 1900.

Zinc. Mining of zinc ore was started in New York in 1915 since which time over 400,000 tons of zinc ore have been mined. The value of the zinc produced amounts to over $7,000,000.
Mineral waters. The output of mineral waters has shown a slight decrease since 1904. The present output is something over 6,000,000 gallons annually as compared with 7,000,000 and 8,000,000 gallons in previous years. The value of the output during the past 20 years has amounted to over $15,000,000.

Molding sand. In 1904 the production of molding sand amounted to 320,000 tons with a value of $262,000. The 1923 production which is the largest during this period amounted to 731,000 tons with a value of $1,212,000.

Other sand and gravel. In addition to molding sand there has been a large increase in the amount of sand and gravel produced. The 1923 production amounted to nearly 10,000,000 tons having a value of over $6,000,000.

Among the other minerals which have contributed to the value of mineral production of the State during the past 20 years are graphite, emery, millstones, pyrite, diatomaceous earth, carbon dioxide, crude clay including slip clay, feldspar, quartz, marl, mica, peat, arsenical pyrites, apatite, gasoline recovered from natural gas, metallic paint, potash, lead and a few ounces of silver, recovered from lead ores, minerals for gem purposes.

More detailed statistics regarding production of the minerals grouped immediately above will be given in another report.

Natural gas survey. New York State has been producing natural gas on a commercial scale for over 100 years. Statistics of early production are not available. In 1904 when statistics were first collected by the State, the annual production amounted to a little more than 2,000,000 M cubic feet. In 1913 the annual production had increased to over 8,000,000 M cubic feet and this production was maintained for a period of 8 years or until 1921 since which time the annual production has fallen to something over 6,000,000 M cubic feet.

As is well known, natural gas has an ever increasing value both for fuel and lighting purposes, and in addition to the domestic supply of the State an additional quantity is brought in from Pennsylvania amounting to over 10,000,000 M cubic feet annually.

With the gradual exhaustion of the present producing gas pools and the probable curtailment of supplies from Pennsylvania, it is evident that unless new supplies are found the natural gas industry must rapidly decline. Thus far about one dozen natural gas pools have been found within the State. These pools are all located from near the meridian of the east end of Lake Ontario to the western
end of the State in Chautauqua county. Already some 1600 pro-
ducing wells have been drilled outside of the oil-producing regions
of southwestern New York.

Inquiries relating to the geological structure of western New York
and the present developed gas fields have been numerous and while
considerable unpublished information gathered during a series of
years is available, it was suggested in my report of last year, that
some field work be undertaken to supplement our present knowledge
of the natural gas fields.

Accordingly, during the summer of 1924 Professor Henry Leight-
ton spent 6 weeks in the field investigating natural gas problems.
The regions examined included the Dansville and Pavilion districts
and in addition some time was spent in studying the gas fields in
Chautauqua county. In the Dansville field Professor Leighton re-
ports that nearly all the wells are located along a north-south line,
with evidence of an anticlinal fold. As this field is comparatively
new, more wells will have to be drilled outside of the present line of
wells to determine whether or not any domed structure is present.

Additional information has been obtained by Professor Leighton
on the Pavilion field. This includes numerous well logs which will
give us further knowledge of the structure of the Pavilion field.

In Chautauqua county many additional well logs have been
obtained by Professor Leighton and these will be of much value in
studying the gas-bearing strata of Chautauqua county. It is hoped
that this field work will be continued during the coming season.

Molding sands. The special investigation of the molding sands
of the Hudson river district, undertaken by C. M. Nevin of Cornell
University, has been completed and the manuscript has been sub-
mitted for publication. The work of Mr Nevin is of a high order
and the publication of his report will meet an outstanding demand
of the molding sand industry. Much additional light is thrown on
the origin and depositions of the molding sands; possible new sup-
plies are indicated and the relations of the various beds of molding
sand are given in some detail.

Supplementary to these field studies, laboratory tests were made
on a large number of samples collected in the field. These tests
were made in conjunction with the American Foundrymen’s Asso-
ciation and are proving to be of much value not only to producers
of molding sand but to foundrymen who actually use the sand.

Another end to be hoped for as a result of these studies is the
development of a system of standardization for the various grades
of molding sand. Such a system is much needed in the industry.
FIELD WORK IN THE SCHUNEMUNK REGION DURING 1924
R. J. Colony

The Schunemunk quadrangle in Orange county includes an area of great structural complexity. Considerable field work has already been done by the writer working in collaboration with Dr C. P. Berkey; during the season of 1924 the work was confined to checking up and verifying some of the results of former field work, more particularly in tracing the major structural lines, and in working over in as detailed a manner as the time would permit some of the extremely complex local areas within the quadrangle.

The area may be very roughly divided into three parts on the basis of structure, stratigraphy and deformation history. These are quite separate and distinct from one another; all of them are complex. They are separated from one another by the major structural lines previously referred to. These three parts consist of:

1 The complex crystalline massive comprising the highlands, extending northeasterly along the entire eastern margin of the area, and also across the southern end of it.

2 The rolling lowland area lying in greater part to the west of Schunemunk mountain, but in part also to the north of Schunemunk and west of the northeastern extension of the highlands; and southeast of Schunemunk, between the crystallines along the southern margin of the quadrangle, and the south end of Schunemunk mountain.

3 Schunemunk mountain proper, including Pea hill and the so-called "Idlewild Syncline" lying immediately northeast of Schunemunk, and the southwest extension in the extreme southwest corner of the quadrangle.

During the field season of 1924 the work was directed to:

1 Tracing and locating the contact between the western and northern margins of the highlands, crystalline complex and the formations comprising the lowland area spoken of. This is one of the major structural lines of the area. The contact in general is a fault contact, especially along the western margin, where the crystallines have been overthrust upon the Wappinger-Hudson River series by reason of movement during the Appalachian deformation.

Additional and later normal faults, of Triassic age, have complicated the situation very considerably.
2 Tracing and locating the great structural break extending from Snake hill, in the northeast corner of the area, southwesterly to Schunemunk mountain; here the break bifurcates and extends on each side of Schunemunk southwesterly. At the south end of Schunemunk the fault relations grow very complex and have not yet been worked out. The entire mass of Schunemunk has apparently been dropped as a fault-block-unit although upstanding above the surrounding softer formations by reason of the superior resistance to erosion offered by conglomerate and graywacke beds which comprise the formations making up the mountain.

3 Detailed study of Pea hill and the "Idlewild Syncline," and the beginning of detailed study of some portions of the area just west of Schunemunk and south of it. These are especially complex regions that will require considerable additional work before they can be satisfactorily interpreted.

PALEONTOLOGY

During the year 1924 two bulletins on the Utica-Lorraine formations of New York were submitted for publication and will appear shortly. The first discusses the stratigraphy of the Utica and Lorraine formations. The Utica formation is shown to consist of three divisions, characterized mainly by its graptolites. It reaches its greatest thickness around Utica. Northward in the Black river valley it is replaced by the contemporaneous uppermost division of the Trenton formation, the Cobourg limestone of the Canadians. The Utica sea invaded from the southwest. A late Utica invasion took place also from the north and is recognized in a black shale formation in the Black river valley, termed the Deer River shale in the bulletin. It is a southern extension of part of the Gloucester shale of Canada. The Frankfort shale is found to be a separate facies of the lowest division of the Lorraine. It is replaced northward by the contemporaneous Atwater Creek shale.

The Lorraine group has been divided into two main divisions, the Whetstone Gulf shale, corresponding roughly to the Eden of the Ohio basin, and the Pulaski shale and sandstone, corresponding to the Maysville. Each has been divided into fossil zones that correspond to the members of the Cincinnatian recognized in the Ohio basin. A series of paleogeographic maps shows the extent of the sea in New York during each of the stages recognized.

The second bulletin contains the descriptions of the first part of the fauna, the lower invertebrates as far as the brachiopods inclusive. A third bulletin to be printed later will contain the large
A gigantic Graptolite, one-half natural size, from the Silurian of New York (Dictyonema crassibasale Gurley)
A new Silurian Graptolite from New York (Medusaegraphus mirabilis Ruedemann)
remainder of the fauna, among them a number of new Ordovician eurypterids.

Another bulletin, on Silurian faunas of New York, has been made ready for the press. It contains descriptions of new faunas from the Bertie waterlime and Lockport limestone. The first is noteworthy on account of its large typically marine element, inclusive of graptolites, associated with eurypterids. This has an important bearing on the problem of the habitat of the eurypterids, much discussed here and abroad in the last decade. The relations of the Bertie fauna to that of the Cobleskill, as well as the lithologic differences, are explained by the conclusion that the Bertie was deposited in lagoons behind coral reefs, as represented by the Cobleskill. The Lockport limestone fauna is entirely different from the usual Lockport limestone fauna with its corals and associated forms, and was found to have inhabited an original channellike depression between the reefs. It thus represents a new Lockport facies of great interest.

The work on a monograph of the graptolites of North America is progressing slowly. Large collections have been sent in from different parts of the United States and from Canada and identification of the forms requested for use in geologic reports. These fossil lists have been furnished in each case and much provisional knowledge has been gained in making them.

The mapping of the capital district has been continued, but has not yet been completed on account of the large area, which comprises four quadrangles.

During the summer and fall various foreign geologists and paleontologists have visited the museum, among them being Doctor Bather, keeper of the British Museum; Professor Reynolds of Bristol University; Doctor Ehrenberg of Vienna University. These, like all preceding foreign visitors, have expressed themselves most enthusiastically not only about the educational character of the paleontologic exhibits, but especially also on the restorations of extinct marine, invertebrate faunas and floras. Thus far only the Devonian life has been represented by such groups, save a Silurian eurypterid group. It is desirable that also the Cambrian, Ordovician and Silurian should be in time represented by similar groups.

Winifred Goldring spent much of her time supervising the execution of the new group of Gilboa fossil trees and the restoration of the fossil forest. This impressive restoration brought up an endless variety of problems both scientific and mechanical. The former had entirely to be solved by Miss Goldring, many of the latter also to a large degree. In connection with this new group an exhibit
of our wonderful Devonian flora was made by Miss Goldring in the subgallery. This exhibit showing the stems, leaves, inflorescences and seeds of the Devonian trees in detail, with the original drawings of the parts accompanying them, will be of much interest both to scientists and laymen.

MUSEUM NOTES

In the achievements of Science there is not only beauty and wonder but also beneficence and power. It is not only that she has revealed to us infinite space crowded with unnumbered worlds; infinite time peopled by unnumbered existences; infinite organisms hitherto invisible, but full of delicate and iridescent loveliness; but also that she has been as a great archangel of mercy, devoting herself to the service of man. She has labored, her votaries have labored, not to increase the power of despots or add to the magnificence of courts, but to extend human happiness, to economize human effort, to extinguish human pain. She has lengthened life; she has minimized danger, controlled madness, trampled on disease. Archdeacon Farrar

Science has done more for the world than politics, more than schemes of education. It has found the basis of a true philosophy of life, a true principle of government, a true path to the mysteries. She is the mother of true religion.

* * *

The laws of Science misdirected by human ingenuity to act against their wont upon materials mutually hostile, antagonistic and indifferent, have put the mark of Cain upon modern civilization. Mankind is showing daily its skill to create and its impotency to control these unnatural and monstrous unions. The mountains of scientific fact heaped together by armies of earnest laborers have grown too great for the most gargantuan appetite to assimilate and they are in danger of poisoning the human community. A misdirected human ambition may bring the world to despair.

* * *

In education there now lie grave questions which our fathers did not raise: How far are schools of special science becoming mischievous to humanity and the State? To what degree are students of such schools pursuing the devious paths which they have devised among the data of Science but which Science herself never created? What is the real objective of such knowledge? The atom does not of itself explode its latent power, nor does the aggregation
of atoms. Is there to be virtue, happiness or content in compelling them to do so in violation of Nature's orderly procedures? The ideals of humanity are not expressed in terms of high explosives, deadly gases, insidious poisons and death-dealing rays, nor was the iron in the heart of the earth designed for a potential weapon of death. We ought to be getting farther away from these things rather than farther in, and it would seem that, in the education of mankind, only schools of humanity and the humanities can bring the antidote to the evil by-products of scientific research.

* * *

All men believe in the same God. He is the God of life. In all the sufficiency of physical fact there can never be too much, never enough knowledge of the procedures of life. Life in its history and the inheritance which controls its present, its normal courses, its abnormal procedures which appeal to highest knowledge for adjustment and correction; the discernment of our own being and the interpretation of our own place, the understanding of the laws that make both the strong and the weak, the derelict, the fool and the genius; this knowledge lies at the basis of human welfare. The laws of life laugh at the statutes of men which are not laid down upon them.

The first discovery of petroleum in America. The little village of Cuba, Allegany county, New York, has the distinction of being the first place in America where oil or petroleum was discovered. This discovery was in 1627—almost 300 years ago—when a French missionary, Joseph de-la-Roche D'Allion, was led to an oil spring by a Seneca Indian. The oil was highly prized by the Indians for medicinal purposes, and for many years petroleum was known by the name "Seneca Oil."

Brief references to Seneca Oil are found in many of the early historical documents. For example Sir William Johnson records in his journal the bringing of some Seneca Oil to Niagara Falls in the year 1767.

For many years the oil found floating on the spring at Cuba was the only source of supply in New York State, a quantity sufficient for medical demands, the only use for oil at that time. The regard of the Indians for the value of this spring is shown by the fact that to this day a tract of land 1 mile square in which the spring is located, is still owned by the Seneca nation.

At present the State Geologist has under way a plan for celebrating in 1927 the 300th anniversary of the discovery of oil in America.
How the Susquehanna river lost its head. The Susquehanna is one of the oldest waterways in this State and it has a very complicated history running far back to the ages when the continental land of New York was but just elevated above the sea-line. According to Professor Herman L. Fairchild, who has worked out the intricate history of this old drainageway, recently published as a bulletin of the Museum, the Susquehanna waters originally headed up in the Adirondack mountain region and flowed almost due south like other streams farther west in New York State, reaching the shifting shores of the sea which were moving ever southward as additions were made through the geological ages to the rising land. Stretched from east to west across central New York is a series of limestone and calcareous shale formations, rocks which are highly soluble in waters which have been flowing over swamp and woodlands. When the surface of New York was old enough to become coated with vegetation, through the long ages of Mesozoic time when the sea had been driven out of this part of the State, the waters flowing from the north, full of carbon dioxide, attacked these limey rocks dissolving them out along their east and west strike until they had cut so deep into them as to create a steady discharge of water from west to east. In other words, they created the Mohawk valley, whose old limestone south bank is an upstanding feature of the scenery known as the Helderberg escarpment. Thus the younger Mohawk decapitated the headwaters of all the older streams originally flowing south from the Adirondack highland and carried off their waters in another direction.

New York City decapitates the Schoharie creek. What Nature and the Mohawk slowly brought about in stealing the headwaters of the Susquehanna, the New York City board of water supply is intensively and rapidly effecting by robbing the Mohawk of the headwaters of its largest tributary, the Schoharie creek. After this stream has wandered many miles over the Catskill plateau, gathering its purest waters, it reaches the village of Gilboa, on its way north into the Mohawk, and it is at this point that New York City has attacked it in order to draw it back south into the new 18-mile tunnel through Shandaken mountain and so on to the wash-tubs of Manhattan. The Schoharie creek itself has been subject to a little stream-robbing during the ages, having lost its headwaters by the drainageways which are now spilling eastward over the Catskill front at Haines Falls and nearby through the cloves leading down into the Hudson.
Why the Shawangunk mountains are peculiar. The beautiful little lakes, Mohonk, Awosting and Minnewaska, draw together every year very select coteries of visitors, few of whom can properly pronounce the name of the mountain range along the comb of which the lakes are spread out. Shongum is an ancient vocable and only those who elide the harsh word into this form can be accepted as strictly orthoëpic. The Shawangunk mountains are unique among the highlands of New York. A heavy mantle of rock made up of rounded white quartz pebbles cemented together by white quartz sand, has been tilted up to an impressive height, broken in two along an Appalachian northeast-southwest direction, the eastern part which once stretched over the lowlands to the Hudson river quite swept out of existence while the broken rock face stands erect and bare along the east face. Over the crest of this rough front and in the depressions of its surface as the remnant mass slopes away to the west, are the picturesque lakes we have referred to. We do not know where the eastern mass of this great sheet of white quartz conglomerate has gone or just what agencies ground it away to this bare crest and comb, although the great glacial sheet is under grave suspicion of having done the most of it. The question of where all these rounded white quartz pebbles which make up the Shawangunk conglomerate came from has been raised again by F. Holzwasser in her study of the geology of the country between Newburgh and the Shawangunk mountains, now being published by the State Museum. Somewhere not far away there must have been an area of land largely composed of quartz and other crystalline rocks, from which the ordinary flow of rivers coming down a fairly steep slope have derived this material and carried it downward out to the sea level, for such a rock as this must have been formed at or not far from a great river mouth. There is no such land today above the sea level, and the geological guide-finger points far to the east beyond the land of the Hudson, and the shores of the Atlantic to a continent which has long since sunk beneath the rising tide of Atlantic waters.

The sea-lilies of the New York rocks. There are not many more beautiful creations of Nature than the graceful and colorful sea-lilies or Crinoidea which grow on the deeper bottoms of our seas. In the very ancient days when the Devonian rocks were laid down as sea deposits, the sea-lilies were far more abundant than now and their little communities or plantations dotted the sea bottoms. There has never been found in these old rocks a richer and more varied plantation of these crinoids than the one unearthed near
the little hamlet once known as Muttonville, now more gracefully
denominated Vincent, in Ontario county, N. Y. Over this bit of
farmland once grew a crop of these wonderful calyxes attached by
long flexible stems, swinging back and forth to the gentle pulsations
of the ocean tides and currents, brilliant in color as the lilies of the
summer and autumn fields which cover their remains.

These old sea-lilies were animals and the botanical garden at the
bottom of the Devonian sea at Vincent was a zoo. In one of the
latest publications of the State Museum (Memoir 16) Winifred
Goldring has given a full account and panorama of the graceful and
complicated creatures from all the Devonian rocks of New York,
150 species in all, and the book constitutes one of the most impres¬
sive scientific works that the Museum has ever issued. Not only is
it an attractive piece of bookmaking but its scientific quality is very
high and its appearance has been applauded in scientific circles. Science says of it: “This superb volume marks an epoch in
American paleontology. The work has been done in a manner un-
surpassed by any scientific publication produced in this country.”
The American Journal of Science says: “With this monumental
memoir the author has placed herself among the leading paleontolo¬
gists of the world and the New York State Museum continues its
existence of 85 years as an intellectual and altruistic beacon.”

How thick was the glacial ice in New York. The ice-sheet
which gave rise to so much of our present landscape topography,
came, of course, to a thin edge at its southern margin. John H. Cook
of the New York State Geological Survey has brought together
evidence from the deposits left by the glacial sheet, that along the
southern margin, when the break-up began, the ice fields stagnated
over lowlands and dissolved slowly like stranded bergs. Northward
during the maximum accumulation, the ice mantle must have been
very thick. A. P. Coleman concludes from his long studies of
Canadian glaciation that a maximum thickness in Ontario would be
approximately one-third of a mile. The New York geologists have
been disposed to put this thickness at a higher figure, Professor
Fairchild having estimated it in excess of 1 mile. Mount Marcy
and the Adirondack peaks in the Marcy cluster have an ice-worn
summit, and Marcy has an altitude of 5,344 feet. This need not
mean that the ice blanket has an actual thickness of the distance of
the Marcy summit down to the sea level. The ice may have risen
from the Adirondack valley surfaces upward in a continuous mass
to those summits, or it may have molded itself in undulations to
valley and mountain alike with a continuous surface but without
the necessity of assuming a vast thickness. Peaks as high as Marcy, if not totally buried and lost under the ice mass, would have been points where ice would have formed and whence it could have been dispersed downward into the mass of the general sheet, but the sum of evidence bearing on our glacial history seems to point to a more considerable ice thickness in New York than Coleman’s conclusions intimate for Ontario.

The Museum and the Falklands. The Falkland islands are the remotest and roughest of the British colonies. There it rains 260 days out of 365 and the wind blows all the time. Out of these distant islands, once French—Les Isles Malouines they are called on French maps—now British, the finest collection of its fossils are in the State Museum. A good half of their geological formations is the same as those of New York and some years ago Clarke made an exhaustive comparative study of the Falkland islands fossils on the basis of collections brought together chiefly by Lady Allardyce, the wife of the governor of the colony, supplemented by materials secured by the Swedish Arctic explorers, Andersson and Halle. Clarke’s extensive account was published by the Brazilian government. Lord Bryce, who visited the Falklands on his celebrated trip to South America, declared they were the dreariest bits of land on earth, while more recently Dr Herbert A. Baker, who a few years ago was directed by the British government to make a survey of the mineral resources of the islands, writes that it is quite impossible to conceive of a more utterly dreary and desolate region “and my chiefest recollection is that of plugging stolidly along on horseback in the teeth of a shrieking wind and against a horizontal rain whose chill penetrated the very marrow of one’s bones.” Doctor Baker writes further:

I personally owe you a debt of gratitude for your memoir on the South American Devonian. I recall countless lonely evenings spent in the remote shack of some inarticulate Falklands shepherd during which the battered volume was produced and the spoils of the day compared with the magnificent plates which adorn it. I have the tattered relic with me now and the pages still reek of the terrible plug tobacco with which one solaced himself after a day of 10 hours in the saddle.

* * *

What killed the fossils? In the more than half-thousand-millions of years that organic life has existed upon the earth, many hundred thousands of species of plants and animals and correspondingly large numbers of genera and families have passed in an endless, ever increasing stream in through the ocean and over the land.
From the beginning of scientific endeavor the question has been asked both by scientists and laymen: What killed these creatures?

There are two fundamentally different forms of extinction; *relative* extinction, where the species change by evolution into different forms, or groups of species change into different genera, and thus while they become extinct as relative species or genera, they live in their descendants; and *absolute* extinction where the form becomes wholly extinct without descendants. Thus the strange straight-shelled cephalopods of Paleozoic time, while extinct as such, may persist in the recent ink-fishes, while the giant dinosaurs are absolutely extinct.

The principal cause of all extinction, both relative and absolute, has been found in changes in the physical environment. These arise from wide changes of the continental outlines, by elevation or subsidence of land masses. The periods of general elevation of the continents have generally been those of severe climates. Cold climates, notably glacial periods, and long spells of dry climate have been especially fruitful of evolutionary changes and of wholesale destruction of species, genera, families and even classes. Such a great period of stress came toward the end of the long Paleozoic era in which most of the New York rocks were formed. The shifting of lands and climates in such times not only traps many creatures where they can not survive but also brings new enemies in contact with species that are not sufficiently protected and so die out quickly. Thus the giant-sloths of South America may have succumbed mainly to the introduction of the sabre-toothed tigers from North America.

Many forms, however, have died without apparent external causes. In such cases internal causes must be assumed. It seems that whole races, after a long climacteric period, reach a racial old age, which shows itself in gigantic creatures, as in the dinosaurs, in the development of excessive protective armor, as plates, spines, horns, antlers etc., and in excessive specialization. In general, highly specialized animals and plants are in greater danger of becoming extinct than the more primitive main lines of evolution, from which these short-lived specialized races branch off. The gigantic forms not only need more food, require slower breeding and a longer period of adolescence, but also seem to lack the necessary equilibrium of their constitution. The persistent long-lived types are therefore always small forms and the "immortal" ones mostly of microscopic size.

An interesting illustration of how an apparently safe form may
rapidly succumb to a lowered vitality has recently been found in Austria where the skeletons of a great number of newly born cave bears were found in a cave where the she-bears were wont to cast their young. In this case the young died shortly after birth, presumably from parasites and the big bears having no dangerous enemies among the beasts of prey, vanished through their lack of means to maintain their vitality. Many of the gigantic creatures of the Pleistocene age have obviously been killed off by man, the most destructive agent of the present era.

On the whole, it seems that while general evolution leads steadily upward and the rulers of the animal world are successively animals with higher brain capacity which through their higher mental powers are able to suppress their lower relatives, the lowly forms, notably the Protozoans and the insects hold more than their own and if unchecked, may cause the extinction of much of the higher organic world.

* * *

A spider traps a humming bird. On the road to Seneca Point, Canandaigua Lake, N. Y., September 15th, 1924, my daughter and I were attracted by faint cries of distress which we took to be those of some small animal—a field mouse or chipmunk perhaps. Turning aside we discovered a ruby-throated humming bird caught in the orb of a spider.

The bird had evidently flown into the web which it had completely demolished in its efforts to escape, but the strands had adhered so firmly to the tips of the primaries of the right wing that it was securely held and fluttered vainly, tethered to a stalk of Bouncing Bet from which it was suspended, not more than 18 inches from the ground. The gossamer threads had coalesced into one stout cable, very glutinous with the combined viscid drops of the web, and remarkably strong.

Sympathy outrunning the passion for research, the captive was set free before there was opportunity to examine the wing, but the inference is that in the struggle the bird had wound itself up and the viscid substance had adhered to the primaries; or that the spider had made an unsuccessful attempt to swathe her victim. Apparently the bird had been a captive for some time and was exhausted by the continued struggle, as its efforts were not vigorous when discovered. When freed, however, it darted away.

The spider was not far off and was soon found in her nest with legs drawn up in the characteristic attitude; a very large specimen
Humming-bird snared by a cobweb
of _Araneus trifolium_, of the deep reddish-brown phase. Having caught a Tartar she had discreetly retired from the conflict. Very probably the bird would never have escaped unaided.

In my acquaintance with the birds of this country this is the first instance which has come to my knowledge of the capture of a bird in the web of a spider. McCook, however, in his American Spiders\(^1\), cites two examples.

Two well authenticated cases of birds taken by a native spider have come under my notice in the vicinity of Philadelphia. A farmer belonging to the Society of Friends, Mr Joseph Lownes, resident in the vicinity of Morton, informed me that he once found a bird, one of the smallest of our indigenous species of Kingster [probably Kinglet is intended], entangled in the snare of a spider, which I judged from the description to be _Argiope cophinaria_. He watched for some time the movements of the bird, and believing that the latter would be finally overcome, he benevolently released it from the web.

Another case occurred on the grounds of the Philadelphia "Rabbit Club," near Fairmount Park, and was related to me by David J. de Haven, the custodian. He saw a large _Argiope cophinaria_ (as it appeared evidently from his description) capture in her web a humming bird. He watched the process of swathing the poor victim until it was completely wrapped around, when he slew the spider and rescued the bird, too late, however, for it was quite dead.

McCook also considers several instances of the capture of mice and small snakes in the webs of _Coras_ (Tegenaria) _medicinalis_ as sufficiently well authenticated to permit his citing them as examples in his work on American Spiders.

In my hasty and necessarily casual view I saw no strands of the web adhering to the feathers of the humming bird, and whether Araneus had actually attempted to swathe her captive or not it was impossible to say. (Stanton D. Kirkham.)

* * *

More aerial engineering. Walking along the Silurian cliffs on the shore of the Bay Chaleur at Black Capes, the writer encountered a triangular retreat in the cliff face rising to a height of about 10 feet. In the center of this space was a blue-gray butterfly spinning around its own axis, first in one direction, then slowly reversing to the other. Closer view changed the butterfly into a flat blue-gray pebble about the size of a nickel, hanging in mid-air, and suspended from the peak of the triangular space by a hawser of cobweb which

\(^1\) 1889, 1: 234.
was connected above with the guy-ropes of a full-orbed geometrical web of an Araneus spider. The side guys of this orb were attached to the sides of the rock ledges where they came together at the apex of this space. There being no place in this open space to fasten a vertical stay, the spider-engineer dropped down to the beach, unreeling his line as he went, took a spliced hitch on a loose pebble, climbed back up on his own line, spinning off another as he went, and having reached his geometrical orb, hauled in the slack on his double sheet till he had lifted the pebble 3 feet off the beach so that it hung in mid-air, its weight giving him just the stay required. Closer examination showed that Araneus had fastened on to this anchor by a double clutch, a pair of strands on each flat side of the pebble, the four strands cemented to the smooth surface and uniting by pairs to form the double-twisted cord of the guy-line. This is not a wholly new observation. Spiders have been known to use heavier objects than this pebble for anchoring purposes, but perhaps
the mode of doing this with a twisted two-strand line, splayed out at the end into a four-strand attachment, is worth special notice. Because of this twisted line the blue-gray pebble hung in mid-air, spinning first in one direction and then in another, as the guy-line wound and unwound.

* * *

A fly in the eye. A stinging stroke in the eye, a continued pain and the removal about twenty-four hours later of some wicked looking maggots, is the brief story of an unusual attack by a fly. The insect, one of our flesh flies, deposits its eggs mostly upon flesh of animals, either dead or wounded. It has been provisionally identified as *Wohlfartia vigil* Walker. The patient was a stone cutter and his first thought was that he had been hit in the eye with a small piece of marble. The evening following, a physician was unable to find the cause of the trouble. The next day an optician observed a cyst in the conjunctiva, and on cutting it out found that it contained several living maggots. This flesh fly evidently struck a blow and at the same time placed several maggots on the eyeball or in a small incision. Attacks of this nature on human beings are not unknown in this country. There are several records of this fly producing boil-like, red pustular sores on the exposed upper parts of young children, especially the neck and arms. These cases occurred in Canada. The one recorded above was in Cattaraugus county.

A related south European, particularly Russian species, *Wohlfartia magnifica* Shiner, is known to attack human beings, the eyes, the ears and the nose being favored, blindness, deafness, or facial disfiguration or even death resulting in some cases. The maggots are armed with stout, horny mouth hooks, very effective weapons for tearing into the more tender tissues.

* * *

The Appalachian air-barrier. Winds are potent agents in the distribution of insects. A detailed study of early spring air currents was conducted by Dr E. P. Felt during 1923 and 1924 while engaged with the New York State Conservation Commission upon gipsy moth control. The easterly components for the period from May 10 to June 8, 1923, for six weather stations in western Massachusetts and the adjoining eastern New York were only 9.1 per cent.
whereas the westerly component was 50 per cent. Data for 1924 showed approximately the same discrepancy.

The records from weather stations were supplemented by the release of over 15,000 hydrogen-filled toy balloons. The drift was very largely easterly, less than 2 per cent of the total balloon mileage being in a westerly direction. The very general easterly drift is also shown by the return from the New England states in 1924 of 472 tags out of a total of 568, but fifty-four being found in New York State, although four of the fifteen balloon stations were in eastern New York and most of the others considerably west of the Connecticut river.

The low eastward component is with little question a result in considerable measure of the north and south mountain ridges and the prevailing westerly winds. Since the gipsy moth is spread largely through the young caterpillars being carried by winds when the temperature is above 60° F., these drift records indicate a presumably slow spread of this serious pest westward in the Hudson valley.

There were some interesting minor developments. In 1923 seven balloons drifted from 110 to 145 miles, twenty-two from 85 to 100 miles, and eighteen from 60 to 75 miles. The average velocity for sixty-five balloons found the day of liberation was nearly 18 miles, although one drifted 65 miles at the rate of 100 miles per hour. The very marked northeasterly drift in 1924 was shown by the return of seventeen tags from the province of Nova Scotia, three from New Brunswick and one from Newfoundland, the last released from Salisbury, Conn., and drifting approximately 775 miles. Another unusual record was made by a balloon drifting to Sable Island, the balloon making about 575 miles from South Londonderry, Vt.

* * *

**A spider monster.** It may be stated as a general rule that the higher the organization of an animal the less is its ability to regenerate lost or damaged tissues. On the other hand, creatures of lowly structure are scarcely inconvenienced by accidents which would be fatal to those more highly developed.

It is of small concern to the crab if it loses a claw, for with a little time and a safe retreat, another will grow. Salamanders and lizards may drop their tails with the comfortable feeling that a new one will in time replace the lost member. Farther down the scale of animal life even more striking regenerations may take place. A flat-worm cut across the middle not only grows a new tail but the cut-off tail
In place of one of the eyes, this spider developed a horn-like process on the front of the head. The horn bears a slender, downward directed branch on the front face. Drawn by W. J. Schoonmaker.
may produce a head of its own; or a starfish may reproduce its entire body from a single arm. While this tendency to replace lost tissues is universal among the simply organized animals, the structures lost are not always replaced in kind. Thus a young crawfish deprived of an eyestalk does not grow another eye but an antenna-like structure, either simple or branched. Something of this kind apparently happens with the loss of the spider's eye.

The appended figure shows a peculiar, almost hornlike structure developed on the side of a spider's head in place of the posterior lateral eye of the left side. The whole face of the spider is distorted and the remaining eyes (spiders usually have eight) are thrown somewhat out of alignment. The left posterior median eye has moved farther to the left and lies at the base of the horn, while the remaining eyes are more nearly in the normal position.

The horn itself is large compared to the size of the spider and tapers to a bluntly rounded point. The front face bears a slender, downward directed process which arises about one-third of the way from the base.

The term "monster" in the title has no reference to the size of the spider for it is a minute creature about one-twentieth of an inch long. (Sherman C. Bishop.)

* * *

Strangely contrasting habits of eel and salmon. The peculiar habits of the eel have excited the interest of naturalists from the earliest times. To the ancients, they were creatures without sex, born of the bottom ooze or of the dew and imbued with powers in keeping with their extraordinary genesis. Traditions such as these have come down to the present day, modified and elaborated, but in no way less fanciful. The sober fisherman may regard the eel as the spawn of the ling or fresh water cod, which he calls "she-eel," and defy you to show him the common eel with eggs in its body; some even point to the "hair-snake," call it a young eel and derive it from a horse hair soaked in water.

It is only within the past few years that anything like the complete life history of the eel has been made known. Observers had long been familiar with the migrations of the eel, the upstream venturings of the young "elvers" in the spring, their methods of surmounting obstacles and their habit of following the smallest trickle to its source; they had known too of the downstream migrations of adult eels in the fall and set their traps and pots in accordance with this knowledge. But how to distinguish the sexes, and where and when
and how the eggs were laid were questions long unanswered. It is chiefly due to the remarkable investigations of J. Schmidt\(^1\) of Copenhagen, that the answers may be given.

The center of the spawning grounds of the American eel lie north and a little to the east of the West Indies. To this area the adult eels make their way for the spawning season which commences in early spring and may continue well into summer. The larval eels, called *leptocephali*, are totally unlike the adults and for many years were regarded as distinct species. When first hatched they are minute creatures, one-half an inch or less in length, ribbonlike and with a glasslike transparency; at this stage they maintain themselves in water at a depth of about 600–1000 feet below the surface. They grow rapidly during the first few months of their existence and move up towards the surface. In this stage they begin their long journey to the fresh water streams of the Atlantic coast of North America and during this migration, they undergo the transformation into “elvers,” the young eels as we commonly know them. The larval stage of the American eel lasts about a year; but that of the European eel, whose breeding area partly overlaps the American, is almost 3 times as long, the length of the period commensurate with the distance to fresh water to be travelled. Transformed into “elvers” they seek the fresh water streams and follow them to their sources, often hundreds of miles from the coast. The sojourn in fresh water is a period of feeding and growth and when maturity is reached (in from 5 to 20 years according to the sex, climate and food), they seek for the last time the breeding places in the sea.

*The Atlantic Salmon*

The habits of the salmon as they pertain to the egg-laying period, are in direct contrast to those of the eel, in that the adult animal seeks the headwaters of fresh water streams in which to lay its eggs after having in most cases reached maturity in the sea. It is fairly well established that the salmon enter the fresh water in two distinct runs, the first in spring or early summer, the second later in the fall, for the purpose of egg laying. The eggs hatch in the early spring and the young fish at the age of 2 or 3 months show the vertical bars, “parr marks” which give them their name of “parrs.” These marks are often retained during the sojourn of the young fish in fresh water, a period of about 2 years and until a length of some

or 8 inches is reached. The "parr" becomes a "smolt" with the loss of its barred pattern and the acquisition of a uniform coat of silver and takes to the salt water where it remains for a year or two. The salmon may return to the fresh waters before fully mature and this subadult is known as the "grilse." The mature fish is the "salmon" and is counted among the best of the game fish. After spawning, the adults of the Atlantic salmon may return to the sea but they are lank and lean after their exertions and go by the name of "kelts." The Pacific salmon on the other hand, dies after spawning. The Atlantic salmon is often landlocked and is capable of maintaining itself without recourse to the sea.

At the breeding season, the male salmon undergoes a remarkable change in appearance and in the structure of the jaws. The cheeks and sides of the body become spotted with orange and the lower jaw develops a strong hook which is armed with large teeth. The skin takes on a thickened and slimy appearance and the fins appear to be fleshy. These are changes which accompany the development of the sexual organs in the male at the breeding period and have their counterpart in the excrescences which develop on certain salamanders under similar conditions.

The strangely contrasting life habits in eel and salmon can find their explanation only in terms of their long history, which runs back far of present time into the records of paleontology.

* * *

Palaeotropism. This is a new word; it makes its bow on this page. It means ancient habits, and it implies the origin, history and significance of present-day habits among the creatures of the living world. It thus designates a special branch of the scientific study of behaviorism. It is quite certain that the habits of all living creatures can be understood only in terms of their origin and gradual acquirement. It is a rather difficult matter to elucidate such adaptations by means of the fossil remains of the ancient world, but it is an interesting field of study which promises results to the patient investigator. As an illustration of the bearing of this suggestion we may cite this case: The worst enemy of the oyster plantations today is the starfish, which embraces the shell in its flexible arms and with a steady but gentle pull obliges the oyster to open his valves, and so the starfish inserts his stomach between the valves and sucks the oyster out and down. Some years ago Clarke found in the Devonian sandstones of Ulster county a vast accumulation of ancient starfish (a single slab in the State Museum carries over 200
of them), scattered among them being the open and closed valves of ancient bivalves, the progenitors of the oysters and clams of today. Many of the starfish and clams were found in such juxtapositions as to make it clearly evident that the former had been feeding on the latter in much the same way as the act is done today, although the starfish were different and the bivalves also different from those of the present. As this feeding habit appears to be at least one hundred million years old, it may safely be regarded as fixed and beyond the reach of "reformers." The story was printed by Clarke in the Centenary Proceedings of the American Philosophical Society.

* * *

How did the barnacles start? The barnacles have long been an outstanding illustration of how an animal may run down hill by adjusting himself to easy conditions of life. They constitute a class of sessile crustaceans that are well protected by a heavy armor of shell consisting of a ring wall of plates and a composite, movable cover. They usually occupy, often to the exclusion of all other organisms, the intertidal zone of the seas, covering rocks and pilings and invading as bothersome pests ships' bottoms and the surface of whales. Owing to their strange and much altered form, they were not recognized as crustaceans until after the young and their development had become known. In these early stages they pass through a free-swimming or nauplius stage which is characteristic of other crustaceans, and during this period and the following Cypris stage in which they have the appearance of the common water-flea, spread out seeking advantageous places for settlement. As soon as these are found, they attach themselves by the head and a rapid metamorphosis takes place by which the head is lost and the very primitive adult body produced.

The barnacles illustrate the far-reaching reduction of a highly organized body through adoption of a sessile mode of life on one hand, and on the other, the success which may crown even a greatly degenerated class of organisms if they have found a hitherto unoccupied niche in the household of Nature. With their broad and safe fixation to the underground, their heavy armor with tightly fitting cover and their ability to obtain plenty of food in the turbulent waters of the intertidal zone where they prefer to live, they are obviously well adapted to their surroundings and therefore flourish to a high degree in the present oceans.

Barnacles like those of the present seas do not begin to appear until early Mesozoic time. Back of them must lie a long history and this history our investigators have been trying to make out.
The Paleozoic rocks of New York have furnished a small number of rare fossils which have been used in the State Museum and seem to shed some light on this strange evolutionary history. The studies made by Doctor Ruedemann and Doctor Clarke indicate that the barnacles took their origin from bivalved, free-swimming crustaceans, such as the phyllopods and this is also indicated by their individual development. These phyllopod ancestors affixed themselves by their heads, back down, so that their feathery limbs could have free play in the water. As a result of this, the two main valves of these pod-shrimps moved for protection towards the ventral or upper side, while two smaller plates, one in front and the other along the line of the back, moved forward and backward respectively, thus forming with the others the beginning of the ring wall. The two main pod-shaped valves, through stresses developed in them after fixation, were split up into five triangular plates each; the middle one of each group, in the earliest known fossil still retains an inverted wedge form, thus completing the outline of the original valve. This line of development led directly to the acorn-barnacles. The common goose-barnacles have a long scaly stem by which they attain a certain flexibility and higher position in the water, but this stem seems to have been originally a part of the head, and stemlike bodies found in the Paleozoic rocks are looked upon as probable ancestors to this group.

The fossil history of the barnacles is an illuminating instance of far-reaching changes in structure, produced by persistent adaptation to a special mode of life, in this case a far-reaching reduction in organization by close affixation. It becomes more and more evident that many of the apparently primitive sessile organisms have started from more highly organized, freely moving creatures, and have sacrificed their higher organization for an easier mode of life.

How society began. Innumerable books have been written about the mutual associations among animals, and it must be understood that the natural associations among human beings, so far as they are not controlled by human intelligence, can be interpreted only in the light of the associations among their predecessors on this planet. "Society" is a broad term. We commonly speak of social insects, ants, bees and wasps, but these are associations each with its own kind, not one kind with another. Yet the living world is full of associations of which the members differ in kind. They are special forms of adaptation. There are parasites, commensals and mutuals, in which the combinations are not always strictly social; they may
be of mutual help or of mutual harm. A tuberculosis germ is not of much help to its host, the patient, although there is no evil intent on the part of the parasite. With it, it is a matter of advantageous adjustment for purposes of feeding and reproduction. A coral fastens itself to the ocean bottom and a worm sits down alongside it. They grow up together, the worm inside the coral. Such associations are enormously abundant throughout Nature everywhere. But the point here is that all such associations had a beginning, had to be started sometime somewhere. Clarke has studied out these associations among the earliest records of life, and some years ago established the fact that as we get farther and farther back among these records of the past the more independent of one another the animals seem to have been. The earliest forms of life seem to have been independent creatures which went out and rustled their own nourishment and did not wait for some neighbor animal or companion to bring it their way. The inference is that social associations are not primitive but acquired and there was a time on the earth when there was no "society."

ENTOMOLOGY

REPORT BY E. P. FELT, STATE ENTOMOLOGIST

The season was unusually cool and backward and consequently many of the early-appearing insects developed much later than usual, a condition which was noticeable even well toward midsummer. Canker worms, for example, were feeding in July and the first brood of the elm leaf beetle did not complete its work until the latter part of the month, some grubs being found even in September.

The changes in the staff incident to the present incumbent's return July 1st could not but affect the continuity of the work. Dr M. D. Leonard, Associate State Entomologist, resigned April 1st to take up special investigations of the Mediterranean fruit fly situation in Spain, with special reference to the possibility of bringing about changes which might facilitate the continued importation of Almeria grapes. The work, from April 1st to the last of June, was conducted by Mr D. B. Young, Assistant State Entomologist, and owing to the very limited amount of assistance available during that period, it was necessary to concentrate on the most pressing matters. The lateness of the season mentioned above helped out very materially, because it delayed the appearance of insects which ordinarily would have attracted notice considerably earlier.
The following is a summary of the observations and work in relation to the various insects.

**Destructive leaf feeders.** A number of injurious caterpillars were unusually abundant. The earliest and one of the most common was the apple tent caterpillar, *Malacosoma americana* Fabr. This insect was unusually numerous in the State and in the southeastern portion, notably in the vicinity of New York City and on Long Island, was so extremely abundant as to arouse very general popular interest. It was even proposed that officials of this State and New Jersey should unite in an effort to promote the immediate destruction of the pest. Owing to the extremely rapid development of these caterpillars and the fact that popular interest was not aroused until the pests had nearly completed their feeding, such procedure was not practicable and no attempt was made to put it into effect.

The fall canker worm, *Alsophila pometaria* Harris was extraordinarily numerous in portions of Westchester county, becoming a veritable plague in certain residential areas.

The ten-lined inch worm, the larva of the lime tree winter moth, *Erannis tilia* Harris, was unusually numerous in the eastern part of the State, partly stripping areas in some sections. The abundance of this insect was evidenced by the appearance of millions of moths about mid-October at lights in cities and villages of the upper Hudson, the insects being noticeable on account of their abundance from the vicinity of Kingston north to Lake George and in the southern foothills of the Adirondacks. Similar flights have also been reported from localities in western Massachusetts and Vermont. This insect is a true canker worm and therefore very local, since spread is dependent upon the very limited crawling powers of the caterpillars and the wingless females. The great abundance of the males indicates a probability of more serious injury another season.

The elm leaf beetle, *Galerucella luteola* Müll, developed unusually late and for a time it looked as though there would be little damage. During July, however, serious injury to the foliage of elms in Kingston, Poughkeepsie and other cities southward became apparent. In not a few cases practically all the foliage on groups or blocks of trees of a considerable extent was so thoroughly skeletonized, in southern Westchester county in particular, that nothing green remained.

**Apple and thorn skeletonizer,** *Hemerophila pariana* Clerck. The distribution of this recently introduced insect was care-
fully worked out in 1923 by Dr M. D. Leonard. A very considerable spread was demonstrated. The investigations of the past season show the insect to be generally distributed, without great increase in numbers, over practically the same area as during the preceding year, except that a notable extension has been recorded in the Mohawk valley, the insect occurring in small numbers as far west as Little Falls. There has not been, except in certain areas near Albany and in the Hudson valley south of Albany, the serious defoliation so characteristic of recently infested sections the preceding year. It appears probable that this relatively welcome condition was due to weather unfavorable to the insect, since the season was unusually cool. Severe injury appears probable in much of this recently infested area if there be a favorable season next year.

**European corn borer, Pyrausta nubilalis** Hüba. There has been little spread of this insect in the eastern part of the State and although there was a considerable extension in the western section, the infestation in this new territory is very light. The insect has increased but little in numbers in the eastern infested area aside possibly from one or two localities and even there the damage has not been extremely serious. The same is true, in a general way, of the western area, there being little increase in sections where the corn has been handled in such a manner as to reduce possibilities of successful wintering to a minimum. Near the center of the western area there has been some increase in stalk and ear infestation. There is nowhere in this State an approach to the very serious conditions which have been observed during earlier years in the southern part of the province of Ontario or in eastern Massachusetts. Variations in the behavior of this insect the present season are indicated by the very serious injury reported from southern Ontario and the relatively little damage in eastern Massachusetts.

**Gipsy moth, Porthetria dispar** Linn. The Entomologist, owing to his connection during the 15 months ending July 1, 1924, with the gipsy moth work conducted by the State Conservation Commission, has enjoyed unusual facilities for noting the various developments. The investigations of air currents have shown, as recorded elsewhere, that winds in the Hudson and Champlain valleys in particular, are much less favorable for the westward spread of this insect than is the case farther east, an extremely large proportion of the drift being easterly. The intensive scouting of the eastern portion of the State in particular, supplemented by special work in other sections, has resulted in finding a relatively few infestations, none serious and practically all within a few miles of the New England border.
The outlying infestations found in western Vermont during the fall of 1923 and the discovery of two infestations in Canada the past season, one in the town of Lacolle, province of Quebec, just north of Champlain, Clinton county, indicate that work upon the barrier zone was started none too soon. The Canadian authorities realize the seriousness of the situation and are adopting every practicable means to exterminate these infestations. The infestations in this State have been cleaned up in a most thorough manner. There is also the closest possible cooperation with federal authorities, the latter concentrating upon keeping the infestation in western New England down to a minimum, thus lessening the probabilities of spread. The situation is well in hand and there appears to be no reason why the pest may not be held in the barrier zone area if the work be continued practically as planned at first.

Birch leaf skeletonizer, *Bucculatrix canadensisella* Chamb. This little insect, sometimes extremely abundant, was somewhat prevalent on gray birches west of Karner. It occurred in but small numbers, there being a marked contrast between the western slopes of the Berkshires and some areas on the eastern slopes where practically all the birch foliage was destroyed by this insect. This is a striking instance of local abundance, the injury being decidedly more marked on the eastern slopes of hills. The insect is reported as destroying birch foliage very generally in southeastern New England.

Birch leaf miner, *Fenusa pumila* Klug. This, apparently a recently introduced insect, was first noted in the season of 1923. Observations during the past summer have shown the miner to be generally distributed in the eastern part of the State, north to the vicinity of Glens Falls and west along the line of the Delaware and Hudson Railroad to Binghamton, in spite of the fact that very little gray birch is found in the latter section. It is also known to occur in western New England. Apparently this species has spread rapidly, presumably being carried by winds in much the same way as in the case of the small moths of the apple and thorn skeletonizer. Our observations indicate an extended breeding season, a factor favorable to rapid spread.

Insects in the human body. There has been, as in past years, close cooperation with the Department of Health and health officers throughout the State and as a consequence, very interesting specimens are occasionally submitted for identification.

One of the most unusual was a very young maggot of a flesh fly, provisionally identified as *Wohlfartia vigil* Walker, which
was removed along with several others from the conjunctivae of a man affected with some conjunctivitis and resident in Cattaraugus county, New York State. This maggot, along with several others, all living, occurred in a small cyst. This appears to be the first American record of adult infestation of the eye, such as is recorded for the European Wohlfartia magnifica Shiner, a species which occasionally destroys the eye of its unfortunate victim. There are several records of this American flesh fly occurring in boil-like sores in the exposed upper parts of the body, especially the necks and arms, of infants, all such cases, however, having been recorded from Canadian localities.

Larvae or grubs of the black carpet beetle, Attagenus piceus Oliv., were received, accompanied by unusual records, one having been vomited by a patient, presumably ingested with unwholesome food, and the other recovered from the vagina of a patient, both from patients residing in Schenectady or its vicinity.

The larva of our webbing or southern clothes moth, Tineola bisselliella Hummel, was removed by a Schenectady physician from the urethra of one of his patients, where it had produced extreme annoyance.

These unusual occurrences of larvae of carpet beetles and clothes moths are merely casual and interesting because of their unusual character. There is nothing to suggest unfortunate changes in habits on the part of these insects. These are cases where sanitation, using this word in a very general sense, was presumably largely wanting.

Bat bedbug, Cimex pilosellus Horv. Occasionally houses sheltering numerous bats appear badly infested with the human bedbug, Cimex lectularius Linn. In most cases the very similar appearing bat bedbug is mistaken for this pest of man, and usually no explanation as to the difference and the less obnoxious character of the bat insect suffices. Such a case came to notice this summer and in cooperation with Dr William Moore of the American Cyanamid Company of New York, the feasibility of destroying both bats and bugs in the walls of a dwelling by the judicious use of calcium cyanide was demonstrated. Experience showed that this could be done without serious inconvenience to the residents and with practically no danger if reasonable precautions were observed.

Winds and the dissemination of insects. The Entomologist, in connection with his investigations of winds in relation to the possible distribution of young gipsy moth larvae in this State, has extended the work along this line by a careful study of the application of these data to the spread of various other insects, notably
the monarch butterfly, *Anosia plexippus* Linn., the cotton moth, *Alabama argillacea* Hubn., and such recently introduced insects as the apple and thorn skeletonizer, *Hemerophila pariana* Clerck, and the birch leaf miner, *Fenusa pumila* Klug. The very wide distribution of such small and feeble insects as gall midges and mosquitoes, to mention only a few of our better known small flies, is certainly suggestive in this connection. It is well known that birds soar for considerable periods and apparently with little muscular exertion. The recent European developments in gliders make it possible for a man to remain in the air for upward of 9 hours, and here again there must be relatively little effort compared to the work involved in flight without the aid of the wind.

It would seem that an insect equipped with organs of flight would intuitively learn how to conserve effort and in not a few instances be content to drift with air currents rather than to rely entirely upon purposive flight. If this be the case, and one can hardly escape such a conclusion in a number of cases, it means a marked change in our opinions respecting insect distribution and may necessitate eventually considerable modifications in local lists, since there has been a general acceptance of these latter as actual records of insects inhabiting certain areas, whereas if there be general dissemination by winds, it may easily happen that species are frequently taken far beyond their normal range. The details of this study are presented in the Entomologist's report.

**A freak specimen.** There was received in midsummer a fifteen-spotted lady beetle, *Anatis quindecimpunctata* Oliv., which had been pierced by a pine needle while still in the soft, tender condition immediately following issuance from the pupa. This specimen was found by Harry D. Longstaff at Horicon on the top of an Adirondack mountain near a cliff remote from habitations. At the time of discovery it was still alive and being supported in mid-air on the tip of an old pine needle. An examination of the specimen showed that there was no crushing or mangling, as would have been probable if the insect had been thrust upon the pine needle by a shrike, for example. The neat entrance and exit of the needle and the color of the beetle showed that it had the soft integument of a recently transformed insect when transfixed. The probabilities are that the branch, swinging in the wind at the time the beetle was just issuing from the pupa, drove the somewhat old and stiff pine needle through the soft, developing insect and lifted it from an adjacent support. It is a most curious accident which might easily happen and generally escapes notice.
Collections. A number of new and very desirable additions to the collections have been made through field work, the most notable being a series of springtails or Thysanoptera, comparatively unknown forms, which were collected by Mr Young. Late seasonal collecting resulted in securing some extremely interesting living specimens showing local variations in certain leaf hoppers and the darkening colors rather common to insects about to hibernate. The arrangement and determination of the insects in the collection has continued whenever opportunity offered, and some progress along this line may be reported.

There have been some unusually important additions to the state collections. A series of minute parasites from R. M. Fouts, Washington, D. C., an authority on the Platergasterinae, was especially desirable. Professor A. C. Kinsey contributed an exceptional series of rose gall wasps, Rhodites, and their galls. Professor C. J. Drake has determined the lace-winged bugs, Tingitidae, contributing a number of unrepresented species. An extremely rare addition was a series of the snow born boreus, Boreus nivoriundus Fitch from L. J. W. Jones of Bainbridge.

Through the activity of Dr M. D. Leonard while he was Associate State Entomologist, material additions were made to the collections in a number of groups as follows: Many Collembola were collected by him and Mr Young and submitted for determination to the well-known authority in the group, Dr J. W. Folsom, who also made highly desirable additions from his own collection. As a result, there is now an exceptional representation of over thirty species of New York State springtails. E. T. Cresson jr, determined the Ephydridae, kindly contributing a number of species, and C. Howard Curran, curator of Diptera, Division of Insects, Canadian Department of Agriculture, identified the Dolichopodidae, generously contributing a number of species and also some very desirable horseflies or Tabanidae. About 100 pinned, undetermined beetles collected in this State and California were contributed by Professor C. R. Crosby of Ithaca.

Very few realize the richness of our insect fauna and the numerous forms which find their way to the Entomologist through one channel or another. Available estimates indicate that there must be living in New York State at least 20,000 different species of insects, each occurring in the four major stages, namely, the egg; the larva, variously known as the maggot or caterpillar; the pupa or chrysalis; and the adult or perfect insect, the latter usually represented by both sexes, males and females, which may differ widely from each other.
The Entomologist is supposed to be able to give satisfactory information concerning any one of these 100,000 different forms of the insects, not to mention being able to recognize the characteristic work of many species upon plants, plant products and other materials. The state collection should contain satisfactory series of all of these stages. The large natural history museums have their custodians of the principal groups, such as the Hymenoptera, Coleoptera, Lepidoptera, Hemiptera and others, these in turn usually being provided with some assistance. Even under such conditions, more material comes in than can be handled adequately.

The State Museum at present has one Assistant Entomologist, who gives much of his time to the classification and arrangement of the insect material, although he may be drafted for and is frequently called to give his attention to other phases of the work. So far as progress in systematic classification is concerned, numerous interruptions, due to the necessities of identifying material transmitted by correspondents, are serious hindrances. Attention has been called previously to the fact that there should be at least one additional assistant entomologist in order that the material in the state collections may be worked up more rapidly and receive more adequate care.

The entomological division of the Museum is receiving more calls than it can meet in a satisfactory manner with the present staff. This was emphasized by Dr. M. D. Leonard, Associate State Entomologist, in charge of the office for more than a year, and is apparent to anyone conversant with the situation and the possibilities along this line.

**Publications.** The Entomologist and the Associate State Entomologist, Dr. M. D. Leonard, prepared a revision of a popular bulletin on the Apple and Thorn Skeletonizer and its Control. This was published as Cornell Extension Bulletin 86 and appeared last May. A third revision, necessitated by the call for information regarding this insect, is now in press. There have been also a number of minor publications, mostly newspaper items in relation to unusually interesting or injurious insects.

The Entomologist’s Key to the Gall Midges, practically a summation of his Studies of Gall Midges, I–VII, is now going through the press and will bring to a well-rounded conclusion an investigation commenced nearly 20 years ago.

**Office matters.** The demands from schools, both teachers and pupils for information regarding the insects of the State, are increasing, and have resulted in the exhaustion of practically all of the available literature especially suited to their needs. It is obviously
desirable that such information be available and in this and the constant increase in demands and inquiries along these lines, is found another reason why provision should be made for a second assistant in entomology.

The correspondence has been conducted along practically the same lines as in earlier years and as usual has covered a wide range of topics in relation to insect life. It has resulted in the accumulation of many desirable data and specimens.

Lectures. The Entomologist lectured on insects and disease before the senior class of the Albany Medical College, in a postgraduate course in infections, diseases and public health conducted by the State Department of Health, and before the staff of the Division of laboratories and research of that department.

A number of other lectures or talks on insects have been given in different parts of the State.

General. The work of the office has been materially aided as in past years, by the identification of a number of insects through the courtesy of Dr L. O. Howard, chief of the bureau of entomology, U. S. Department of Agriculture, and his associates. There has been effective and close cooperation with the State Department of Farms and Markets, particularly the bureau of plant industry, the State Conservation Commission, especially the gipsy moth office, the State Department of Health, the State College of Agriculture at Cornell University, the State Experiment Station at Geneva, the county farm bureaus and various public welfare organizations. A number of correspondents have donated specimens and rendered valuable service by transmitting data respecting various insects and assisting in other ways.

ZOOLOGY

Report by Sherman C. Bishop, State Zoologist

The Zoologist and his assistants are charged with the development of the Division of Zoology and with the care and preservation of the materials relating to zoology which are deposited in the New York State Museum. Under this general head, the following items may be considered:

Field work. The collections are being constantly added to by active field work. During the past year excursions were made for the purpose of collecting those southern elements in the New York fauna which reach the northern limits of their distribution on Long Island and the southeastern counties. Particular attention was given the arachnids, reptiles and amphibians and large series were
collected at Mineola, Riverhead and Montauk Point, Long Island; on Gardner's Island and in the Ramapo mountains in Rockland county. Shorter trips were made in the vicinity of Ithaca and Freeville, Albany, Middleburg and Westerlo. Various Pennsylvanian localities were visited where certain species, rare in New York, are to be found in abundance.

**Care of collections.** Zoological specimens require constant care and attention. The bird and mammal skins and mounted specimens are subject to the attack of moths, beetles and other museum pests and alcoholic specimens are ruined with the evaporation and escape of the preserving fluid. Mounted specimens on exhibit and exposed to strong light, fade and must be replaced, they become covered with dust and must be cleaned at least once each year. This part of the work has fallen to the taxidermist, Arthur Paladin, who has been over the entire series. Specimens stored in formalin or alcohol include forms which can be preserved for study in no other way. Some fifty thousand containers receive the attention of the Zoologist or his assistants at least once each year.

**Classification and arrangement of specimens.** A considerable part of the time of the Zoologist is spent in classifying and arranging the materials brought together by field work, by purchase, by exchange or by gift to the Museum. Groups which heretofore have been neglected, have received the greatest attention and the Museum now has a representative collection of spiders and other arachnids, reptiles, amphibians and fishes. The exhibit series of fishes is particularly noteworthy and has been enlarged by the recent purchase of several well-mounted specimens of fresh and salt water species.

**Research.** During the past 8 years Professor C. R. Crosby of Cornell University and the Zoologist have devoted themselves to the study of the very extensive arachnid fauna of the State with the view of presenting a descriptive account of this greatly neglected group. The materials accumulated and studied emphasized the necessity of much preliminary revisional work before the general account could be attempted. Several of these fundamental studies have been prepared and published and others are in manuscript.

The Zoologist has also given considerable attention to the study of amphibian life histories and a general account of the salamanders of the State has been prepared. This account attempts to express the present knowledge of the habits and life history of the species found in the State.
Publications. During the past year the following papers by the Zoologist have appeared in the State Museum reports or other journals:

A Revision of the Pisauridae of the United States. New York State Museum Bulletin 252.


The following papers are in press:

Notes on the Mating Habits of the Sparrow Hawk.

Records of Some Salamanders from North Carolina and Pennsylvania.

Two New Spiders from the Blue Ridge Mountains of North Carolina; by C. R. Crosby and S. C. Bishop.

The following papers have been prepared:


Notes on the Spiders of the Southeastern United States with Descriptions of New Species; by C. R. Crosby and S. C. Bishop.

Lectures and demonstrations. During 1924 the Zoologist delivered twenty lectures on subjects pertaining to zoology and museum work.

The Division of Zoology has continued to cooperate with various state and city agencies and by arrangement with the superintendent of the Albany schools, Dr C. Edward Jones, a series of lectures and demonstrations was given at the Museum to acquaint the teachers in the public schools with the value of the collections and exhibits of the Division of Zoology, in the teaching of nature study and biology. Over 300 teachers availed themselves of the opportunity offered and were supplied not only with material for classroom use but with a specially prepared printed leaflet outlining certain features of the work.

Work of the assistant to the Zoologist and the taxidermist. The Assistant to the Zoologist and the Taxidermist are both performing very useful and necessary work and relieve the Zoologist
of much of the routine labor connected with cataloging and care of specimens. But the field of zoology in New York State is such a vast one that the Zoologist must limit his major investigations to a few groups and give only casual attention to other subjects which are of no less importance. A specialist trained in ichthyology should be added to the staff of the Zoologist and, because of the value and size of the Museum's collection of shells, the services of a conchologist should be secured.

In February 1924, the assistant to the Zoologist, Maria Seguin, tendered her resignation and was succeeded by Walter Schoonmaker who was appointed to the position in March 1924. Since his appointment, Mr Schoonmaker has been engaged chiefly in the collection and preparation of specimens for the Museum's collections and in the routine work of cataloging and record keeping. As opportunity permitted he has prepared a series of some eighty line drawings, illustrating various reports in preparation by the Zoologist.

The taxidermist has cleaned the entire series of mounted birds on exhibit and has mounted a number of new specimens to replace those which have suffered much from overlong exposure to strong light and dust.

**Accessions.** The most notable additions to the collections during the past year have been made by members of the staff. Extensive series of arachnids, amphibians and mammals have been collected and added to the study collection. Professor C. R. Crosby of Cornell University collected and sent to the Museum a remarkable series of the smaller spiders belonging to the Erigoneae, among which were several species new to science.

**New groups.** No new large groups may be attempted with the present arrangement of cases in Zoology Hall but a series of small habitat groups showing some of the peculiar features in the life histories of salamanders has been projected and active work started. The Division of Zoology is handicapped by its lack of a trained preparator whose energies might be devoted to the reconstruction of the existing groups and to the development of new groups which require much accessory material in the way of restorations in wax and plaster.

**ARCHEOLOGY**

**Report by Arthur C. Parker, State Archeologist**

**Scope of the Archeology Division.** The Division of Archeology embraces the several related divisions of anthropology, namely, archeology, ethnology, folk lore, language and comparative anatomy.
It is the duty of the Archeologist to conduct field investigations in archaeology whereby the ancient village and burial places of the aborigines of this State are discovered and excavated; to make studies of the surviving aborigines with reference to their customs and material culture, as represented by survivals; to collect and collate the unwritten literature and folk thought of the Iroquois; to make studies of the language of these natives and to make necessary somatological and osteological measurements and observations.

Material so collected falls into two general groups: exhibition articles for display in the Museum, and literary material for our archives.

The object of all this effort is to discover all there is to know relating to the past and present condition of the aborigines of our State and to make this information available to the public. There is more than an ordinary interest on the part of our citizens in the subjects that fall within our scope as is attested by the attention given by all the great educational institutions and museums within our Commonwealth. It has fallen to us in a large measure to supply the facts to the world, and the demand is an insistent and an increasing one.

During the past 18 years this division has practically revised the whole concept of aboriginal archeology within the State and it has been the fortune of this Museum through its researches to sift out the differences in the various native cultures, and indeed to have defined most of them for the first time.

**Staff.** In the prosecution of the work devolving upon this division of the Museum there has never been the necessary staff of experts trained to make the desired investigations. The Archeologist alone, (with occasional manual help without training), has conducted all investigations. In so large a field and one wherein the facts are constantly retreating, good work has often been retarded and made impossible, especially in the face of the pressure of routine clerical work in the office. For the past 10 years there should have been four trained employees, two research men and two clerks. For lack of this help the Archeologist has been compelled to abandon many important lines of endeavor to become an office machine devoting his time to answering letters and doing clerical work. This has been a most discouraging feature of the work.

**Condition of the collections.** The collections are constantly growing and as far as possible new specimens have been placed in the proper exhibits. These collections are examined from time to time and kept in proper condition.
The ethnological groups in the Myron H. Clark Memorial Hall are a source of constant care and it is necessary to watch them for the various sources of deterioration, such as moths, lack of moisture, electrical defects, dust and structural changes. These exhibits, attracting many thousands of visitors, are in excellent repair and their condition is a tribute to the workmanship of the artist who installed them.

Public interest. It has been the custom to report the interest of the public in our researches and exhibits. There has been no diminution during the past year. Hundreds of visitors, at times a score or more each day, attest the eagerness of the public for knowledge concerning the several subjects to which attention has been given. Personal calls have also been received from writers, historians, playwrights, artists, directors of pageants, teachers, missionaries and other specialists, as well as many anthropologists. Supplementing personal calls have been numerous letters of inquiry from interested students. More than 3000 replies to such inquiries have been sent out, many of them involving considerable study to provide the needed information.

The public press has been particularly insistent that information be furnished and there has been scarcely a day when a reporter or special writer did not seek interviews or facts concerning some subject under the division. The press has been friendly and has given the Museum and especially this division wide publicity.

Albany tercentenary. The project to celebrate the 300th anniversary of the founding of Albany brought about a concerted effort to enlist the help of certain special bureaus of the Education Department, including the Archeology Division of the Museum.

Through arrangements made by H. C. Wardell, the Archeologist delivered a radio address on “Indian Methods of Signaling” from the broadcasting station at Rensselaer Polytechnic Institute in Troy in February. On this occasion through the cooperation of the Boy Scouts of Albany a message from Mayor Hackett of Albany was read inviting the people of the State to attend the tercentenary celebration. The Boy Scouts relayed the message from the mayor’s office to the Troy broadcasting station in 55 minutes, a distance of 9 miles, thus providing an excellent method of contrasting the speed of the Indian runner with the speed of modern radiotelephony.

The celebration took place on June 1st to 4th. It was the work of our division to stage the Indian pageant and to supply a historical paper for the tercentenary program.
Field researches in archeology. During the summer months a survey was made of certain archeological sites in Erie, Cattaraugus and Chautauqua counties, where several interesting and important localities were discovered. Later a detailed survey was made of sites along the upper waters of the Allegany and Genesee. The object was to trace the migrations of the Iroquoian people. The importance of this region must be emphasized for along these headwaters are several precontact sites of much significance to archeologists. This region is as yet unexplored by competent archeologists.

During August a survey was made of the sites embraced in the Penn Yan, Yates county, quadrangle. It was discovered that the occupation of this important section of the State was mostly early Algonkian. Sites were examined at Penn Yan, Branchport, Guyanoga, Hanfords, Bluff point, Yatesville, Second Milo, Wayne, Tyrone, Lamoka lake and Dresden.

During the last week of August a site near Levanna, Cayuga county, was examined. This site proved to be a prehistoric Algonkian site of the third Algonkian period. It belonged to the same cultural horizon as the Owasco lake outlet site excavated in 1915. The short time given the work demonstrated its importance. The pottery is especially worthy of study. The plan calls for a continuation of this excavation during the season of 1925. The site has not heretofore been touched and therefore remains an unspoiled source of archeological information of rare value.

Archeological reservations. The rapidity with which archeological sites are being destroyed points out the ultimate end of these sources of aboriginal prehistory. The time is not far distant when our most important ancient monuments will be obliterated. Interest should be aroused whereby typical examples may be preserved.

This division has repeatedly called attention to this need and has made recommendations to influential societies and commissions seeking the establishment of public parks and scientific reservations on the sites of Indian fortifications and villages.

The site of Indian falls and Spirit lake provides an ideal setting for a scientific and scenic park. For many years this locality in Genesee county has been a camping and picnic ground where thousands of visitors gather on holidays. History, geology, Indian traditions and scenic beauty all conspire to make the spot desirable. Attention was directed to this locality at the 1923 meeting of the Genesee County Historical Federation and an attempt was later
made to interest the State Council of Parks in the project to acquire it as a state reservation, but the land owners put prohibitive prices on their property and the plan was temporarily abandoned.

The plan to acquire the Flint Mine hill as a reservation has received several setbacks but an implied promise has been given that it will be included under the state park bonding proposition passed at the 1924 election. If this reservation is acquired, we shall have an archeological monument of major importance and one unique in the history of the State.

Field of research in archeology and ethnology. Scattered throughout the State are numerous Indian village, burial and fortification sites. These are of many cultures and date from remote times to so recent a time as 1779 when General Sullivan destroyed the towns of the Iroquois confederacy. What we know of these sites and of the specimens which they cover is only a fragment for only a limited amount of money and the attention of only a few experts has been given to the problem. Numerous amateurs have dug into mounds and earthworks and quantities of specimens, usually termed "relics" by collectors, have been unearthed. These specimens, however, have a meaning far greater than mere relics. Each is an important link in the problem of America's prehistory, making necessary detailed observations. Amateurs seldom know how to make such observations and because of this, much information is forever lost. Added to the destruction by untrained collectors is the wear and tear of commerce and husbandry. Sites are destroyed in building operations, by flooding due to the elevation of water surfaces by dams, and by farmers who find it necessary to level the walls of ancient forts for agricultural purposes.

The field of archeology in New York is a rapidly diminishing one. Thorough work must soon be done or it can never be done.

In the ethnological field is to be found the living Indian, descendant of the Iroquois. Twenty years ago there was something to be found of his native products but today little remains. There is an occasional individual belonging to the native cult who still has a few products of his ceremonial society or perhaps a few articles connected with the preparation of corn as food, but the past has gone and a great opportunity has been missed.

There are some Indians who even yet cling to the older traditions and who remember some portion of their native folk ways. These should be sought out and enlisted as informants. The older men who kept up the ceremonies of the "long houses" have passed on to the mysterious hereafter and today we have none like Baptist
NEW YORK STATE MUSEUM

Thomas, Albert Cusick, Edward Cornplanter, Delos Big Kittle and Ward Snow, all of whom helped so much 10 years ago.

These fugitive facts point out the urgent need of immediate study of what does remain. Intelligent research can not be conducted by amateurs or by untrained anthropologists for the results would be uncritical and empirical. The approach must be by way of sure knowledge, experience and training.

BOTANY

Report by Homer D. House, State Botanist

Scientific investigations. The investigative work of the State Botanist during 1924, and since the latest published report of this office, has been directed chiefly toward the completion of the Annotated List of the Ferns and Flowering Plants of New York State, which was published as Museum Bulletin 254. This has involved much bibliographic work as well as study of the plants in the state herbarium and in the field. Collections and field studies have been carried on during the past year in the vicinity of Newcomb, Essex county; the east shore of Lake Ontario, in Jefferson county; the vicinity of Oneida lake in the central part of the State; and in other localities. Collections of plants from these localities, which are of scientific interest have been incorporated into the herbarium. The ferns and flowering plants of peculiar interest are to be reported upon in the State Botanist's Annual Report under the caption "Local Flora Notes," and the fungi under "Notes on Fungi." A large number of fungi, both parasitic and saprophytic, chiefly of recent collection, have been studied in collaboration with Dr John Dearness, and will be reported upon under the heading "New or Noteworthy Species of Fungi."

Contributions to the state herbarium. The additions to the collections since the previous report in the form of contributions and exchanges are presented in the following list of contributors, which also indicates the number of specimens received from each:

<table>
<thead>
<tr>
<th>Name</th>
<th>Specimens</th>
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<tbody>
<tr>
<td>Roy Latham, Orient</td>
<td>522</td>
</tr>
<tr>
<td>E. Bartholomew, Stockton, Kan</td>
<td>100</td>
</tr>
<tr>
<td>Dr Harold St John, Pullman, Wash</td>
<td>100</td>
</tr>
<tr>
<td>Leland S. Slater, Coxsackie</td>
<td>60</td>
</tr>
<tr>
<td>Mr &amp; Mrs E. A. Eames, Buffalo</td>
<td>56</td>
</tr>
<tr>
<td>C. A. Brown, Albany</td>
<td>50</td>
</tr>
<tr>
<td>M. S. Baxter, Rochester</td>
<td>35</td>
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<tr>
<td>F. A. Ward, Cortland</td>
<td>35</td>
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<tr>
<td>Dr J. I. Davis, Madison, Wis</td>
<td>30</td>
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<tr>
<td>E. P. Killip, Washington, D. C.</td>
<td>30</td>
</tr>
<tr>
<td>William C. Ferguson, Hempstead</td>
<td>15</td>
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<tr>
<td>S. H. Burnham, Ithaca</td>
<td>9</td>
</tr>
</tbody>
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Additions to the herbarium. The total number of specimens which have been added to the collections from all sources during the year is 1355, of which 510 were received by contribution or exchange. Considerably more than 1000 specimens were received by exchange or contribution, but only 510 of them have been incorporated into the collections. In connection with the curatorial work, the services of recent temporary assistants, Helen LaForce and C. A. Brown, have been most satisfactory and indispensable. The bulk of routine and curatorial work in the State Botanist’s office is of such bulk that permanent assistance is urgently needed in order to carry forward any extensive work in botanical research.

The collections by the State Botanist, noted above, were made in the following counties of the State: Albany, Essex, Hamilton, Jefferson, Lewis, Madison, Oneida, Onondaga, Oswego, Rensselaer, Warren, Saratoga, Schenectady, Montgomery and Herkimer.

Identifications. The State Botanist’s office has been called upon to identify 425 specimens of plants including many edible and poisonous mushrooms during 1924. These identifications were requested by 130 persons, mostly by mail, some of them, however, by personal visit to the office. The demand for this service varies considerably from year to year. It is a service of distinct value to those people of the State interested in its wild plants and mushrooms, and the fact that there is not a larger demand for it seems to be due chiefly to the fact that it is not generally known that such service is available and free of charge.

Visitors. The extensive collections of the state herbarium, including as it does a very large number of type specimens of fungi, is frequently consulted by specialists in various lines of economic or purely scientific botanical research. Such facilities as the herbarium room affords is always placed at their disposal and personal attention is directed to making their visits productive of the best possible results.

Lectures. During 1924 the State Botanist delivered eight lectures before various organizations upon the subject of plant life, wild flowers and wild flowers needing protection.
SINGING SPIDERS

By Sherman C. Bishop

Every one is acquainted with the songs of insects which in many cases are as characteristic of the various species as are the songs of birds. On the other hand, it is probably not generally known that some spiders are provided with delicate organs which are of such a character that we must assume them to be for the purpose of producing sound. In fact, some of the larger tarantulas are said to produce a loud hissing and one instance is reported in which the spider reared itself upon its hind legs and gave a most astonishing and terrifying demonstration. But the sounds made by the smaller true spiders have probably never been heard by human ears although it might be possible to listen to a spider chorus if our gross senses could be tuned to the proper pitch. The sounds produced by these smaller spiders are doubtless for communication between the sexes and not, as in the case of the tarantula mentioned above, for the purpose of terrifying.

Spiders are not to be regarded as having a voice of the character possessed by birds or mammals where the sound is produced by cords or membranes set in motion by the passage of air. In spiders the device may be compared more accurately with certain types of musical instruments or the simple combination of a stick and a picket fence when the first is drawn rapidly over the second. The general structure of the sound-producing (stridulating) organ is essentially the same in the various spiders in which it is developed but it is differently disposed in different species and appears in the most unexpected places. Two elements are concerned in the production of vibrations; first, a rasplike surface over which, second, a picklike spine or series of teeth is rubbed or drawn. This arrangement necessitates the placing of one of the parts on a movable base and the pick is usually developed on one of the appendages. In some cases, however, contact is between structures on the thorax and abdomen or between two appendages. The stridulating organs are developed in pairs but in the following descriptions only one of the two is considered.

In the family Theridiidae some of the males possess a file on the thorax and a pick composed of several teeth on the abdomen. In some of the spiders of the family Linyphiidae the lateral side of the chelicera of the male is furnished with a file which is scraped
by a pick borne on the inner face of the femur of the palpus; in others, a pick on the basal joint of the hind legs rasps the file developed on a plate on the under side of the abdomen. In still other members of this family, the basal joint of the front legs is involved.

The structures mentioned are described more in detail under the accounts of particular species and may be understood by reference to the appended figures on which the parts are indicated. In Asagena americana (figure 1), the males have the stridulating organs conspicuously developed. The file is a roughened plate at the side of the cephalothorax near the hind margin and is scraped by a series of spine-bearing teeth borne on a ridge on the side of the front margin of the overlapping abdomen. The abdomen is capable of considerable movement up and down and the parts are thus brought in contact.

Theonoe stridula is an exceedingly minute spider, less than 1/25 of an inch in length. It belongs to the same family as Asagena and has the stridulating organ in practically the same position. The pick is developed as a short, broad tooth on the front of the abdomen and may be apposed to a striated area on the hind part of the thorax.

Lephthyphantes nebulosus (figure 2) is a representative of the family Linyphiidae in which the males have the file borne on the lateral face of the chelicera. The pick is a spinose hump on the inner side of the basal part of the femur of the palpus and is shown enlarged in figure 3. By moving the palpus up and down the pick is rubbed against the file.

The males of some of the species of Tmeticus seem to be provided not only with a file on the chelicera as in Lephthyphantes, but with another on the plate which is developed on the front part of the under side of the abdomen. Tmeticus obtusus has such an arrangement and the pick is a toothlike projection on the hind margin of the basal joint of the hind leg. By a lateral movement of the hind leg the tooth may be drawn across the roughened plate of the abdomen (figure 4). Here is provision for a duet by one individual, for the striae of the cheliceral files are much finer than the corrugations of the abdominal plates and the soprano of the mouth parts may be accompanied by the baritone of the hind legs.

Troglohyphantes is the name given to a group of small spiders, some of which are only about 1/12 of an inch in length. They are cave-inhabiting species with more of an excuse for a signaling device than the spiders which live in the light. In the male here
figured, the hind face of the basal joint of the front leg is provided with a file which may be brought in contact with the pick on the front face of the second joint of the second pair of legs. This is not so complicated as it seems, as may be seen by reference to the figure (figure 5).

Organs which may serve for the reception of vibrations are not so easily discovered in spiders but in one species of Leptoneta examined there was not only a stridulating organ but an arrangement of hairs which may well serve an auditory function. On the side of the tibia of the male palpus there is a long stiff hair which has the end flattened, grooved and somewhat twisted. The grooved tip holds the end of a long slim hair which arises nearer the base of the segment. This device has recently been described as the original crystal detector.¹

¹ Ent. News. 36: 144, fig. 1. 1925.
EXPLANATION OF FIGURES

Fig. 1 Asagena americana Emerton. Male showing the file of the stridulating organ on the hind margin of the thorax and the pick, consisting of several teeth, on the front of the abdomen.

Fig. 2 Lephtyphantes nebulosus (Sundevall). In the male of this species the file is borne on the outside of the chelicera and the pick on the inner side of the femur of the palpus.

Fig. 3 Lephtyphantes nebulosus (Sundevall). Top view of the base of the femur to show the pick.

Fig. 4 Tmeticus obtusus Emerton. The file of the stridulating organ is conspicuously developed on the under side of the abdomen near the front, the pick on the hind margin of the basal joint of the hind leg. This species apparently has another file on the chelicera.

Fig. 5 Troglohyphantes sp. The male has the file developed on the hind face of the basal joint of the front leg and the pick on the second joint of the second leg.

[68]
FUNDAMENTAL LINES OF NORTH AMERICAN GEOLOGIC STRUCTURE

By Rudolf Ruedemann

The present paper is a continuation of studies recorded in a recent essay of the writer. In this the writer endeavored to show that the trend-lines of the folds of the Precambrian rocks, together with their foliation, schistosity, and the longitudinal direction of the batholiths, form a complex of phenomena that are causally connected, and that exhibit uniform directions over immense tracts of the earth. There are three such tracts of super-continental

1 Published, save some additional data, in the American Journal of Science, ser. 5, vol. 6, 1923, p. 1-10. A confusion of the figures in this article and the large demand for copies of this and the earlier publication on the Precambrian continents have made a reprinting of the two papers desirable.


3 The truth of these premises was doubted by Professor W. J. Miller in a paper read at a meeting of the Geological Society of America. It is not necessary here to enter into a discussion of Professor Miller's assertions, since they are based on individual views that do not agree with the consensus of other students of Precambrian geology. We may, however, mention in passing that recent exhaustive studies of the granite batholiths of Germany (Hans Cloos, Tektonik und Magma, Untersuchungen zur Geologie der Tiefen, Abh. d. preuss. landesanstalt, n. Folge, H. 89, 1922; S. v. Bubnoff, Die Methode der Granitmessung und ihre bisherigen Ergebnisse, Geol. Rundschau, Bd. 13, H. 2, 1922), demonstrate the dependence of the structure of the batholiths on directive lateral pressure (richtender Seitendruck or Gebirgsdruck), active during and after the intrusion, and thus serve still more to isolate Miller's assertion of the absence of true folding in the Precambrian rocks or its merely local character resulting from batholithic intrusion. Likewise in his denial of uniformity of folding in the Precambrian rocks based on a wrong procedure of investigation. It is possible to study a building with one's fingers on the bricks to look for minute cracks and breaks, or one may stand farther back to survey its general architectural lines. The writer in the above-mentioned essay has preferred the latter method. It is true that there may be local discrepancies with the general fold directions, as indeed there are in every fold-system. Thus there occur in the uniformly N. 20° E. trending system of the folds of the slate belt of eastern New York, small cross-folds, one north of Troy, another south of Albany. To unduly emphasize these merely local structures would only serve to hide and confuse the general picture of the fold system and thus to miss its meaning. Also some of the Canadian authors (as notably T. L. Tanton and H. G. Cooke) have pointed out that minor cross-folds are often superimposed locally on the major folds of the Precambrian rocks, while others, as M. E. Wilson (1913, 1919), have emphasized the fact that batholiths may locally affect the structural trends, but are themselves subjected to the same deformations as the intruded rocks, which deformations were caused by true mountain-building crustal movements.

The uselessness of further discussion of the points raised by Miller is clearly indicated by Alling's final statement in his paper, "The Origin of Foliation and the Naming of Syntectic Rocks" (American Journal of Science, ser. 5, vol. 8, 1924, p. 12-32) which reads: "He (Miller) is the only one of the Adirondack geologists who believes, 'that the Grenville strata of the Adirondacks have never been highly folded or severely compressed.'"
size which are termed Archi-America, Archi-Gondwana and Archi-Eurasia. The same tracts appear as continents in early Cambrian time and persist, more or less fractured, as fundamental units of the surface of the earth throughout geologic time.

Professor Charles Schuchert, in a letter to the writer, has termed the complex of Precambrian trend-lines the "grain" of the continent. This appropriate term will be applied in this paper to the Precambrian folds and their associated phenomena, as the major axes of intrusion, foliation and schistosity.

North America, as the remaining portion of Archi-America, is controlled according to the author's reconstruction (op. cit., fig. 1), by a grain whose trend is roughly northeast in the eastern portion of the continent, east to west in the middle, and south to north and
northwest in the western plateau region; the whole forming a southwardly convex, asymmetric curve, whose western limb is more sharply turned upward than the eastern one. (See figure 1.) For details the reader is referred to the former paper.

Precambrian Grain not Controlled by Later Influences

In the present paper it is intended to suggest briefly to what extent the grain has controlled the later geologic history of North America.

In this analysis, the question arises first whether the Precambrian grain of the continent, as we see it today, has not been altered by later influences instead of having been the controlling factor.

It might be assumed that the original grain of the continent ran from east to west, as we find it in the middle and least disturbed portion of the continent, and that the marginal trends (northeast in eastern America and north in the western plateau and Rocky mountain regions) were superimposed upon an original, different trend by later folding, presumably through oceanic spread from the Atlantic and Pacific oceans respectively. It was, however, shown in the earlier paper that there is fair evidence of the Precambrian existence of the trend-lines in both marginal belts, as seen, for example, (1) in the direction of the batholiths found by Berkey and Rice in the Highlands of New York; (2) the northeast direction in eastern

Canand beyond; (3) the observation of ancient interlocking northeast-southwest gneiss bands by Keith in the Asheville quadrangle; and (4) the presence of bars running in that direction in the Appalachian geosyncline from earliest Cambrian time on; and for the Rocky mountain region in the cases of original directions found in the blocks or "Islands" left undisturbed by later folding, as in the block of north Wyoming and south Montana (see Ruedemann 1922, p. 87-89). The original presence of these marginal trends is further attested as early as Lower Cambrian time, by the direction of the seas in the two original geosynclines of the continents, and even before that time in the western trough by the Belt terrane extending in the same direction.

It was, for these reasons, concluded in the earlier paper that the Appalachian and Pacific fold systems are in their general directions.

Figure 2. Diagram of Paleozoic generalized epicontinental seas.
"posthumous" \(^5\) in character to the Precambrian trend-lines of the same areas, and it has also been shown that the main orogenies were preceded in the same region by prenuncial folds, finding expression in "barriers" separating basins, as notably in the Appalachian region where these structures have been indicated by Ulrich and Schuchert.\(^6\)

**Composite Picture of American Epicontinental Seas**

A composite picture of the epicontinental seas of North America from the beginning of the Cambrian to the Tertiary\(^7\) is that of two long geosynclines, one in the east, the other one in the west (as represented in Schuchert's chart of the Upper Georgian), and these are connected by one or more east-west arms. (See figure 2.)

The two long sea-arms represent the two geosynclines that are already present at the beginning of the Cambrian and were again and again inundated wholly or partly, the invading sea coming in at one or both ends or somewhere in the middle from the nearest ocean. These two geosynclines became submerged either singly or jointly, wholly or partly, in every period from the Canadian to the Mississippian eras. They are, so to speak, the axes of the epicontinental sea system. From them proceed seas in an eastward direction from the Cordilleran geosyncline, and westward from the Appalachian geosyncline, in a more or less irregular fashion, but on the whole in broad east-west bands, as shown in Schuchert's chart of Acadian time, and in many succeeding ones (Ozarkian, Canadian, Ordovician, Middle Silurian, Upper Devonian, and Lower Mississippian). There is thus furnished a fundamental picture of the early Paleozoic seas of North America, consisting of two northwardly diverging narrow basins, connected by transverse bands. One can not fail to note the general agreement of this pattern with that of the grain of North America, as given by the structure of Precambrian formations.

As Paleozoic history proceeds, a further tendency to inundation from the north and south sides of the continent develops, from the directions of the present Hudson bay and the mouth of the Mississippi. This becomes distinct in lowest Trenton, late Rich-

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\(^5\) The term "posthumous" used by European authors is rather misleading, as suggesting a complete, "after death" cessation of orogenic movement, and would be better replaced by epigonic or postclimacteric or a similar expression, denoting revived orogenic activity along the former trend-lines.


\(^7\) The reader is referred to Schuchert's paleogeographic charts in his "Paleogeography of North America." (Bul. Geol. Soc. Amer., 20, pls. 46-101, 1910) and Ulrich's charts (in Compte-Rendu, XII Intern. Geol. Congress, 600, 1914) and in Bassler's "The Cambrian and Ordovician Deposits in Maryland" (Maryland Geol. Surv., 1919), as illustrating this chapter.
mond, and Silurian times (see Schuchert’s charts of Rochester-Osgood, Louisville and Guelph time). In the Devonian it has disappeared again, but throughout Carboniferous (Bradfordian, Fern Glen, Burlington, Saint Louis, Chester, Upper Pottsville, Upper Pennsylvanian and Permian) time the invasions all come from the Gulf of Mexico.

FIGURE 3. Strikes of Paleozoic rocks. Compare with fig. 1. Asterisk indicates strike changed by faults in Burnett area, Texas.

This latter group of inundations, which appears as subsequent in regard to the grain of the continent, in contrast to the consequent inundations along the geosynclines and transverse bands, may be due to the uplift of the eastern and western regions caused by the increased folding arising from the geosynclines and the consequent sagging of the middle of the continent. The rather irregular alternations of the north and south invasions, on the other hand, may be due to a sea-saw motion of the continent, with alternating uplift.
in the north and south, perhaps resulting from alternating "continental creep" and "suboceanic spread," as suggested by Ulrich for smaller differential oscillations.\(^8\) It is perhaps still recognizable in the present marine transgression of northern Canada as far south as Hudson bay, and the Tertiary invasions of the lower Mississippi region and along the south and southeast coasts.

### Present Strikes of Post-Precambrian Rocks in General Agreement with Grain

(See Fig. 3.)

The present strikes of the Post-Precambrian rocks are a composite result of the original inclination of deposition in the epicontinental seas, the later tiltings and foldings, and the variable depths of erosion. Notwithstanding these many factors, the general strike directions of the formations still furnish a fairly accurate picture of the original grain of the continent, as a glance at the geologic map of North America will show. In the east the general direction (see figure 3) is still northeast, in the west it is northwest,\(^9\) and in a small central area, south of the Great lakes, the predominant direction of the strikes is east-west. It was this phenomenon, in part, which led the writer to assemble the facts of these strikes in a former paper\(^10\) and point out the symmetric arrangement in the elements of the Paleozoic platform of North America.\(^11\)

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\(^9\) To which extent the grain here controls the coast-lines of the Paleozoic seas, as well as the strikes of the Paleozoic rocks, is for example, well illustrated in an interesting paper by E. B. Branson on the Paleozoic formation margins in Missouri (American Journal of Science, ser. 5, vol. 8, no. 46, 1924, p. 317-29), which brings out the fact that the Paleozoic formation margins, now deeply buried, run parallel from southeast to northwest in Missouri, hence with the grain of the country.


\(^11\) The dependence of strike of the Post-Cambrian rocks on the original grain of the continent is also shown somewhat in the distribution of the oil pools. The latter are arranged somewhat approximately in a U-shaped figure, the east arm extending on the west side of the Appalachian mountains and the west arm on the east side of the Rocky mountains. It is interesting to note that from north to south the oil pools are found in approximately younger formations along these guide lines. The oldest oil pools are of the Trenton, and are within the arms and nearest to the Precambrian nucleus. Along the east guide line the age ranges from Devonian in the north to Tertiary in the south.

The California oil fields correspond to guide lines on the western side of the great synclinal and folded area along the Pacific.

The oil pools mark the localities of predominant ancient coast lines and shallow basins. (C. A. Hartnagel.)
Near the middle meridian line of this platform, positive and negative elements, which find their expression in the Cincinnati-Tennessee geanticline on the one hand, and the Michigan basin on the other, have considerably disturbed the original structure. But even the chart of the "Paleozoic positive elements" as given by Schuchert (op. cit., pl. 49) shows quite distinctly in the trends of these elements the influence of the original grain of the continent, the positive elements being roughly arranged as the arms in the letter U (see figure 4).

Figure 4. Relation of positive elements (stippled; after Schuchert) to grain of continent, indicated by black lines.

Major Lines of Present Physiography still Influenced by Grain of Continent

It seems that even the major physiographic features of the continent as seen at present are still more or less controlled by the original grain of the continent. This is, of course, distinctly shown
in the mountain systems of the east and west of the continent which are posthumous or epigonic to the original Precambrian fold-directions, or general trend-lines. The U-shaped system of Precambrian trend-lines is, further, unmistakably preserved in the general outline of the continent. The grain reappears likewise through a long series of successive causal connections in the great water courses of the Yukon, Mackenzie, and St Lawrence rivers, as well as in the main tributaries of the Mississippi, the Missouri, and the Ohio rivers, while the Mississippi itself has found its bed in a mid-continental depression that appears already in Paleozoic time, but does not become pronounced until Cretaceous time.

Of the Great lakes, Lake Superior, "largely an original rock basin, or perhaps a syncline" (F. B. Taylor, 1915), clearly follows the grain, even in the more southerly direction of its western arm, which is parallel to a local bend in the directions of the Precambrian rocks; and Lakes Erie and Ontario fall in line with the St Lawrence system. If the two last mentioned lakes are, as the glaciologists assure us, merely old river courses, overdeepened by glacial action along weaker belts of rocks, they indicate by their direction that these preglacial rivers also followed in their southwest courses the grain of the continent. It is, however, possible that they are, to some extent at least, also influenced in their direction by the gentle folding that is observable in southern New York.

12 Rollin T. Chamberlain in an excellent paper on "The Significance of the Framework of the Continents," recently published (Jour. Geol. vol. 32, no. 7, 1924, p. 545-74) has submitted good evidence for his conclusion that "the framework of the continents is an outgrowth of the special stress conditions developed near the borders of continents." He states:

The recurrence of folding and faulting in these situations and the further development of the frame in later ages by the rise of new folded chains in general alignment with the earlier ones results; (1) from the natural recurrence of more or less similar stress conditions, particularly in these critical border zones of great segments; (2) from geosynclines bordering early ranges developing weak belts which later, by yielding to the stresses, localize subsequent foldings; and (3) the influence of the earlier structural grain in determining to some extent subsequent yielding.

This inference of the initiation of the folding near the borders of the continents would also seem to explain the less intensive, and sometimes less regular, folding of the Precambrian rocks observed in the interior of the continents, notably America and Africa; as well as the distinct evidence of the presence of Alpine mountain ranges near the continental borders in Precambrian time, as, for instance, the one just indicated by Barrell's studies (The Nature and Environment of the Lower Cambrian Sediments of the Southern Appalachians: Amer. Jour. Sci., ser. 5, vol. 9, 1925, p. 1-20). Barrell infers a region of high Proterozoic Appalachians in the southeast of America, that produced the Ocoee conglomerate, "comparable to Neocene conglomerates which flank the Himalayas."

and that represents a weak northwestern extension of the Appalachian folding. Also this would bring them again indirectly under the influence of the grain of the continent. Lakes Michigan and Huron are, so to speak, strike-lakes, following the subcircular strike of the weaker Silurian rocks (mainly those above the Niagaran limestone) around the Michigan basin. The location and the form of their basins are therefore due to influences reaching back to late Paleozoic time, aside from the final glacial factors (glacial erosion and damming and post glacial tilting).

**Conclusion**

It is believed by the writer that the original grain of the Precambrian foundation of the continent reappears in the main directions of the epicontinental seas, principally of the Paleozoic era, in the present general strikes of the rock formations, and in the major physiographic features of the continent, notably its general outline, the mountain systems, the principal river courses and the major axes of some of the Great lakes.
GLACIAL BOULDERS
IN
EASTERN, CENTRAL AND NORTHERN NEW YORK
by James H. C. Martens

Introduction

The object of the writer's field work in the summer of 1923 was the investigation of glacial boulders in certain parts of New York, for the purpose of locating boulders of known or determinable sources to be used in a study of the directions of boulder movement by the continental ice sheet. Attention was given chiefly to boulders of igneous and metamorphic rocks, many of which have been carried long distances by the ice.

Since it was of course not possible to look at boulders over any large proportion of the total area of the State in the limited time available, the work was confined to those parts where it was hoped that most could be accomplished. Boulders were examined at frequent intervals along the heavy dotted lines shown on the two maps of parts of the State (figures 2 and 3), and also at a few localities in Madison and Chenango counties, in southeastern New York in Dutchess county, and along the south edge of the highlands in Westchester and Putnam counties. It was thought that such an examination of boulders in somewhat widely separated regions would be more likely to lead to definite conclusions about the directions of boulder transportation than would more intensive work in a small area, and would, moreover, give a better idea of the advisability of continued field work along this line.

Boulders of some rocks which were not easily determined in the field or which were considered to be worth detailed study, were sampled for laboratory study, but it was not necessary to take samples of nearly all of the boulders observed and noted. In making the counts of boulders classification was necessarily based on the field examination.

In a paper in preparation under the joint authorship of Professor A. C. Gill and the writer there will be a more detailed discussion of the boulders of the central part of the Finger lakes region, with descriptions of some of the rarer types and evidence on which the correlation of the boulder with the parent rock was established. When considering the occurrence or nonoccurrence of boulders of
PART OF EASTERN AND CENTRAL NEW YORK

X and number indicate locality of count in table I.

route followed in examining boulders

0 10 20 miles
certain rocks at the different localities visited, the presence of boulders of similar rocks in the Finger lakes region, particularly the vicinity of Ithaca, will be referred to. The writer wishes to express his thanks to Professor Gill for permission to use some of this unpublished information in this report.

**Nature of the Deposits Containing the Boulders**

The progress to be made in the study of boulder dispersal in any glaciated area depends upon a number of factors, among which may be mentioned: the character and extent of the formations from which the boulders are derived; the bed rock, the topography, the kind of glacial deposits; and the amount of cleared and cultivated land in the area where the boulders occur.

Ground moraine and recessional moraine deposits are the principal ones in which the boulders were examined. Where the fine material has been washed out from among the boulders by streams
or where the boulders have been piled into stone walls it is often possible to easily see large numbers of them within a short time.

Where the morainic material has been covered by stratified deposits, boulders carried to their present position by glacier ice may be seen only where streams have cut through the overlying deposits. In the vicinity of Albany, till is exposed in the valleys of some of the small streams, while over most of the area only stratified sand and clay are in sight.

Little attention was given to the composition of the gravels deposited from water near the ice front during its retreat, but in general they seem to have about the same lithologic character as the pebbles of the ground moraine in the same region. That is, material which is strictly local or derived from only a short distance away is very abundant, while pebbles from distant sources are comparatively rare.

Correlating a Glacial Boulder with Its Source

In this paper the conclusions as to the parent mass from which boulders of a particular rock are derived are based mainly on petrographic similarity of the boulder with the supposed source. For ideal conditions all of the country from which the boulders have come should be known geologically; and each rock used in studying boulder distribution should be confined to a small compact area. Boulders of unusual rocks may be most easily traced to their source because such rocks occur over small areas only and are often described more thoroughly than the more common ones.

To learn much more about the ice movement and to be sure that the source decided upon is the correct one, the limits of distribution of the particular kind of boulders should be investigated and the boulder train should be traced back to its source. Where it is not practicable to do this on account of the distances involved, concordant results obtained from the study of several kinds of boulders in the same area will decrease the chances of serious error.

Boulders versus Striae as Criteria of Glacial Movement

Most of the observed glacial striae must have been made during the waning stages of the ice age when the ice front had retreated back nearly to where the striae are now found. At that time the direction of ice movement and therefore the bearing of the striae, was greatly influenced by the local topography. This is well shown by the large number of instances in which the scratches indicate
that the ice followed the valleys and was deflected by the hills. Of course topography is one of the major determining factors in the movement of a continental glacier even when and where the ice has a great thickness, but under such circumstances only the large topographic features and not small details would need to be considered. In the rather few instances in which glacial scratches are found on hill tops the scratches are of more value in showing the trend of ice movement at the height of glaciation.

From the study of boulder dispersal more can be told about the general directions of movement when the glaciation was near the maximum, since probably the greater part of transportation of boulders from distant sources occurred at this stage of the ice age. Very interesting results have been obtained by the study of boulder trains from closely limited sources, over comparatively small areas. We need only refer to the boulder trains from Iron hill,\(^1\) Rhode Island, Mount Ascutney,\(^2\) Vermont, and the recent investigations in Finland.\(^3\)

**Causes of Error in Arriving at Conclusions**

Even when reasonable care is used there is possibility of error in drawing conclusions as to glacial motion from the distribution of boulders. Some of the boulders may have been carried part of the way by floating ice or running water. In some regions also there has been multiple glaciation and boulders may have been carried in quite different directions during successive glacial epochs, or at different stages of a single ice age.

There is also possibility of error in concluding that boulders of a certain rock derived from a great distance away are absent from a certain region when in reality they are there in very small numbers. The full weight of this objection may perhaps be realized when one considers that only one or two or three boulders were found of some of the rocks for which the location of the parent mass seems best proved. It is therefore highly probable that at other localities where boulders of the same rock are present in about the same amount they might be overlooked entirely in any search which could reasonably be made.

The correlation of the boulder with the source has already been discussed, but it may be mentioned in passing that there is always the possibility of another mass of exactly the same rock occurring

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elsewhere, either in some place which has not been explored, or entirely covered by surficial deposits in a region which has been mapped as accurately as conditions would allow.

Figure 4

Sources of Glacial Boulders in New York

Only those sources are considered here from which boulders in the parts of the State where the writer has worked on this problem are likely to have come. This discussion does not refer to particular
boulders or definite source localities, but rather to geological forma¬
tions and regions. More exact localities and additional references to
published descriptions on which the identifications of boulders with
the parent rocks were partly based, will be given in a subsequent
section of this report. For convenience the sources are first classi-
field geologically and geographically as follows:

**Paleozoic**

Sediments not much folded or metamorphosed occurring in central, western,
and northern New York, the St Lawrence valley in Quebec, and parts of
Ontario.

Sediments folded and metamorphosed occurring in a narrow belt along the
east side of New York, and a large part of Vermont and the eastern town-
ships of Quebec.

Volcanic and intrusive rocks of the folded Paleozoic region in the eastern
townships of Quebec and in northern Vermont.

Younger intrusive rocks of the Monteregian hills petrographic province in
Quebec.

**Precambrian**

Metamorphosed sediments and igneous rocks, mostly volcanic, in the eastern
townships of Quebec; not always distinguishable from the Paleozoic rocks of
the same region.

Precambrian areas of the Adirondacks and Ontario and Quebec north of
Lake Ontario and the St Lawrence river; sediments very highly metamor-
phosed; great variety of igneous rocks.

Any correlation of boulders from the large area of unmeta-
morphosed Paleozoic should be based on paleontologic evidence as
well as lithologic character. Under favorable conditions the geo-
graphic as well as the stratigraphic position of the source could be
determined from the fossils contained in the boulder.

Folded and more or less metamorphosed sediments of Paleozoic
age extend through Vermont, the adjacent eastern part of New
York and the northward continuation of the Green mountains of
Vermont into the eastern townships of Quebec. The strike of the
rocks as well as of the belt as a whole changes from north to con-
siderably east of north after it passes into Quebec. The most com-
mon rocks are slate, sandstone, limestone or marble, and graywacke.
Associated with these metamorphosed sediments in northern Ver-
mont and the eastern townships of Quebec there are igneous rocks,
both volcanic and intrusive. The volcanic rocks are mostly meta-
morphosed to a schistose condition, and are scarcely to be distin-
guished from the Precambrian volcanics of the same region. The
intrusive rocks are not well enough known so that boulders of them
could be separated from boulders from the north of the St Lawrence
in the Precambrian areas, except in the case of a few of the more
unusual varieties.
The Monteregian hills are a series of denuded volcanic necks and laccoliths in southern Quebec which were so named by Professor F. D. Adams on account of their similarity to Mt Royal, the best known one of them. There are eight of these isolated hills which rise from the St Lawrence river plain. They have all been described petrographically in more or less detail. On account of their small extent and the occurrence of some unusual types these Monteregian rocks are especially adapted to the tracing of boulders.

The main intrusive masses of all of these Monteregian hills are syenitic rocks and essexite, and they are often characterized by the presence of feldspathoid minerals. In addition to the principal rock masses composing the Monteregian hills there are smaller satellite intrusions of a great variety of rocks, in the form of dikes and sheets. Descriptions of typical specimens of the most common rocks of each of these Monteregian hills as well as some of the extreme varieties and contact facies have been published.

The Precambrian rocks of the eastern townships of Quebec occur in three belts or areas which have a general strike about north-northeast. In order from west to east these are: the Sutton mountain, the Stoke mountain, and the Lake Megantic areas. Only the Sutton mountain area will be briefly described, since this is the best known and the only one from which it is thought that there is much likelihood of boulders having reached New York.

At the boundary between Vermont and Quebec the outcrop of the Precambrian rocks of the Sutton mountain anticline is about 20 miles wide and its eastern edge is 10 miles west of Lake Memphremagog. It is the continuation into Quebec of a part of the Green mountains, and extends about 20 degrees east of north, with gradually decreasing width. The central part of the range is made up of gneissic, micaceous, quartzose and talcose schists. On the sides of the range there are green chloritic schistose rocks which have their best development along the western side of the range and extend from the Vermont boundary to the St Francis river in the vicinity of Richmond. The chlorite schist is believed by Ells to be a metamorphosed igneous rock of dioritic composition. The main belt of chloritic and dioritic rocks is 6 miles wide near the Vermont line and narrows toward the north. Copper minerals occur frequently in the green chlorite schists.

The Precambrian areas of the Adirondacks and of Ontario and Quebec north of Lake Ontario and the St Lawrence River contain

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the following as the principal rocks: the Grenville series of metamorphosed sediments, including quartzites, limestone and various gneisses, with which are usually associated amphibolites; intrusive rocks which include the granite-syenite series, which is a really most important, and anorthosite, gabbro and diabase. The geology of these Precambrian areas is so complex that it is often not possible to tell to which of the major geologic divisions a detached boulder belongs, much less to determine the exact locality of the source. Some of the rocks such as the granites, granitic gneisses and anorthosites, have little variation over large areas, so that even if one is sure from which series of rocks a certain boulder is derived this is little help in locating the source geographically. This statement should not be taken to imply that there may not be some small rock masses in these Precambrian areas having such special characteristics that boulders from them can be traced long distances, but merely that the writer is not able to point out such areas at present.

The possibility of boulders having reached New York from some of the less metamorphosed areas of Keewatin and Huronian rocks in northern Quebec and parts of Ontario has been considered. From what has been published it would seem highly probable that rocks similar to some or all of the metamorphic rocks of the eastern townships of Quebec, may occur in those areas and that boulders from them may have reached some parts of New York. The field work was not extended over a large enough area to make it possible to decide this interesting point.

Counts of Boulders

At several localities counts were made of the boulders exceeding a certain size, usually 1 foot maximum diameter, to determine the relative numbers of boulders of the different rocks present. These counts do not give even an approximation to the total composition of the till at these places, because most of the counts were made on or near bed rock so soft or so much bedded and jointed that it was broken up into small pieces and was therefore not included in sufficiently large amount in proportion to the harder rocks from more distant sources. The foreign boulders were sometimes counted and

the more abundant, although smaller, pieces of the local rock disregarded, especially where the latter is shale or other thinly bedded rock, or where it is so near the surface that blocks have become detached by post-glacial weathering.

It is believed that these counts will show somewhere nearly the relative numbers of boulders of the various rocks from distant sources, although, as stated above, not giving any idea of the large amount of local material among the smaller particles of the till.

It is not to be wondered at that difficulty was encountered in classifying the boulders of gneisses since their origin and relations are not always apparent in some of the parent rock masses which have been carefully studied. An attempt was made in most cases to separate under the name of Grenville gneisses those whose composition and structure indicates that they are of sedimentary origin. This could not always be done consistently, however, because of the occurrence of mixed gneisses as well as many of doubtful origin. Many gneissic boulders were classified as granitic gneiss which approximate the mineral composition of granite; it is highly probable that these are not all gneissoid granites, but are in part sedimentary Grenville gneisses which can not be recognized in detached boulders. Those which were assigned to the Grenville without hesitation include: gneisses with much garnet or sillimanite or both; finely foliated biotite gneisses; gneisses approaching quartzite in composition.

Local Details of Field Observations

Southern Putnam and northern Westchester counties. Familiarity of the writer with this region leads him to the conclusion that little can be expected from the investigation of boulders in it without using paleontologic evidence for the identification of fossiliferous boulders or spending an unreasonable amount of time looking for boulders of igneous and metamorphic rocks for which a probable source can be located. Boulders from only short distances away are of the largest sizes and on account of the resistant nature of much of the rock, make up an even larger proportion of the coarser part of the drift than the local materials do in the regions of unmetamorphosed sediments. Boulders of the slates, limestones etc. of the Taconic mountains to the north are by no means rare, but there seems to be little chance of tracing these back to closely limited sources.

One small boulder of anorthosite and one of a type of gabbro like that in the Adirondacks are not of much significance because
such boulders are already known to occur in southeastern New York, and these two boulders were near the mouth of Peekskill creek where they might have been carried a considerable distance by water.

Most of the drift deposits in this region are loose gravels, and if typical close packed ground moraine exists it is fairly rare and of small extent.

**Dutchess county.** The country for a few miles back from the Hudson river near New Hamburg and Wappinger Falls was examined for boulders. There are few which are not of local origin or so similar to the local rocks that any distinction would be difficult. These boulders from nearby sources are mostly the Wappinger limestone and the slates and grits of the Hudson river series.

The most common rocks from distant sources are granitic gneisses and garnet gneisses, which may have come from the Adirondacks or various places in Canada, or perhaps in part from some nearer locality such as the small area of Precambrian rocks near Pine Plains in northern Dutchess county. Boulders of such varieties of gabbro as are common in the eastern part of the Adirondacks are present in much smaller numbers but are not extremely scarce. There are also a very few boulders of gray anorthosite like that of the main body in the northeastern Adirondacks.

As far as these facts go they merely support the idea that the ice moved straight south parallel to the Hudson valley and they do not give any additional information as to the movement of ice into the valley from more distant regions.

**Schenectady to Ballston Lake.** In the vicinity of Scotia on the north of the Mohawk river, about 98 per cent of the boulders are sandstone and shale of local origin. Nearly all of the other boulders are of quartzite (Potsdam sandstone) and Grenville gneisses. The gneisses are mainly biotite garnet gneisses such as occur at many localities in the Grenville series in the Adirondacks. There are a few boulders of gabbro and anorthosite. The largest ones of any kind are scarcely a foot in diameter.

Around Burnt Hills and Ballston Lake village boulders are more abundant and of larger sizes, especially in the valley to the south of this lake. In a field a few hundred feet from Ballston Lake station the kind of rock in 100 successive boulders 1 foot or more in diameter was noted, care being taken to avoid the selection of particular kinds by counting all the boulders in a definite area. The results are shown in table 1, column 2.

The largest boulders at this locality are 8 or 9 feet in diameter and are of gabbro. No boulders were seen here for which it was
thought that a definite source could be located. If small pieces had been counted there would have been more of the local rock, since this easily breaks up into thin slabs. The relative proportions of the other rocks would have remained the same or nearly so. The large number of gabbro boulders and the small number of granite is rather surprising. The abundance of Grenville gneisses would be expected from the large area which this series occupies in the southeastern Adirondacks.

One mile south of Round Lake station and 4 miles west of Ballston Lake, 200 consecutive boulders along a fence were counted and the number of each kind noted with the results shown in table 1, column 1. It will be noted that this differs from the preceding mainly in the larger amount of Potsdam sandstone and smaller amount of gneisses and gabbro.

**East side of Hudson river northeast of Troy.** Around the west end of Tomhannock reservoir 10 miles northeast of Troy search was made for boulders but few were found except in the riprap along the shore of the reservoir, for which they had presumably been gathered from the surrounding country. Near Schaghticoke in the Hoosic valley boulders are also scarce and small. The boulders in the riprap mentioned above are mostly sandstone and slate in various stages of metamorphism. They frequently contain quartz veins.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>Counts of boulders in the Mohawk valley and the northeastern part of the southwestern plateau</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOCALITY NUMBER</strong></td>
<td><strong>SIZE OF BOULDERS</strong></td>
</tr>
<tr>
<td>Granite</td>
<td>3.5</td>
</tr>
<tr>
<td>Granitic gneisses</td>
<td></td>
</tr>
<tr>
<td>Quartz syenite</td>
<td>19.9</td>
</tr>
<tr>
<td>Grenville gneisses</td>
<td>16.5</td>
</tr>
<tr>
<td>Amphibolite</td>
<td>9.5</td>
</tr>
<tr>
<td>Gabbro</td>
<td>4.5</td>
</tr>
<tr>
<td>Diabase</td>
<td></td>
</tr>
<tr>
<td>Anorthosite</td>
<td></td>
</tr>
<tr>
<td>Alkali syenite</td>
<td></td>
</tr>
<tr>
<td>Vein quartz</td>
<td></td>
</tr>
<tr>
<td>Hornstone</td>
<td></td>
</tr>
<tr>
<td>Potsdam sandstone</td>
<td>39.0</td>
</tr>
<tr>
<td>Hudson River shale and sandstone</td>
<td>22.5</td>
</tr>
<tr>
<td>Unclassified sandstone and limestone</td>
<td>3.5</td>
</tr>
<tr>
<td>Oneida conglomerate</td>
<td></td>
</tr>
</tbody>
</table>

1 One mile south of Round Lake station, elevation 240; bed rock is Hudson river formation.
Ballston Lake village, elevation 300; bed rock is Hudson river formation.

Two miles east of Johnstown, elevation 880; bed rock is Hudson river formation.

Two miles southwest of Johnstown, elevation 540; bed rock is Hudson river formation.

One half mile west of Altamont, elevation 800; bed rock is Hudson river formation (not included in the count).

Four miles northwest of Cobleskill, elevation 1400; bed rock is Hamilton formation.

Two miles northeast of Edmeston, elevation 1600; bed rock is Hamilton formation.

Clinton, elevation 700; bed rock is Clinton formation.

They may have come from anywhere in a large area to the north and northeast. One essexite boulder at Tomhannock reservoir and one boulder of nephelite syenite at Schaghticoke hill are doubtless from some of the Monteregian hills in Quebec. The essexite may be from either Shefford mountain or Mount Johnson, the rocks of both of which it closely resembles, while the nephelite syenite does not agree exactly with any description which could be found.

Ballston Spa to Amsterdam. From Ballston Spa to the west and southwest for the first 5 miles the general composition of the larger boulders is much the same as at Ballston Lake. The gabbro, quartzite, Grenville gneisses and syenitic and granitic gneisses are the only kinds other than the local rocks that are at all abundant.

Within 5 or 6 miles to the north and northeast of Amsterdam, the rocks just mentioned are abundant as boulders, in addition to the local rock which is limestone. Anorthosite boulders are much scarcer than might be expected in this region. In a length of stone wall made from stone removed in clearing the fields there were counted fifty-five boulders of gabbro, four of anorthosite, and four of diabase, other kinds being disregarded. A boulder of essexite from Mount Johnson was found 3 miles northeast of Amsterdam.

Tribes Hill to Johnstown. Another comparison of the relative abundance of anorthosite and gabbro boulders was made 3½ miles northwest of Tribes Hill where, in a 200 foot length of stone wall there are twenty-five gabbro and six anorthosite boulders. A count of one hundred boulders 1 foot or more in diameter along a fence at 800 feet elevation 2 miles east of Johnstown, along the north boundary of the Fonda quadrangle, and a count of two hundred boulders along a fence 2 miles southwest of Johnstown, gave the results shown in table 1, columns 3 and 4 respectively.

At these two localities only about 5 miles apart in an east-west direction the coarse part of the drift is seen to be of approximately
the same composition, as one might expect. None of the boulders seen is of rocks which are known to be confined to a small area in place, so they are of little value in telling anything about glacial movement. Probably all of the igneous and metamorphic rocks are from the Adirondacks and not from any more distant Precambrian area.

**Altamont to Gallupville.** Boulders other than the local limestones and sandstone are not very abundant in this district but where the fields have been cleared such boulders are easily examined since their round shape keeps them from being built into the walls and causes them to be laid on top. Quartzite, gneisses and gabbro are the commonest kinds of rock found in the boulders from distant sources. For the results of a count of boulders near Altamont see table 1, column 5. Along Fox creek between West Berne and Gallupville there are banks of till containing many striated boulders, but nearly all are of the local rocks.

**Schoharie to Central Bridge to Cobleskill.** Around here boulders of igneous and metamorphic rocks seem to be more abundant than along Fox creek a few miles to the east. The largest are not over 5 feet in diameter. Boulders of gabbro are more abundant than near Ithaca, although the actual number of all kinds of boulders is less per unit area near Schoharie. Along the lower part of Cripplebush creek 2 miles north of Central Bridge, Schoharie county, boulders of gabbro are by actual count 5 times as numerous as those of anorthosite and average about the same size.

Four miles northwest of Cobleskill a count of boulders other than the local sediments was made with the results shown in table 1, column 6. Shale and limestone boulders from within a few miles make up about half of the boulders more than a foot in diameter and a much larger proportion of the smaller fragments. In this case no distinction was made between the various granites, granitic gneisses, and other gneisses but there are few if any boulders of true massive granite.

**Richmondville to Schenevus to Oneonta.** North of Richmondville between there and South Valley the common gneisses and quartzite were the only rocks noticed in the boulders transported from a distance. The greater part of the field stone is made up of flat slabs of the local rock. In Beards Hollow near Richmondville, in a distance of about one-half mile along the creek bed there are eight anorthosite and fourteen gabbro boulders.

Along the valley of Schenevus creek and Susquehanna river from Schenevus to Oneonta boulders are scarce and none of those seen
needs especial notice here. The same applies to the parts of the main tributary valleys which were examined in this vicinity.

**Oneonta to Clinton.** In passing in a general northerly direction from Oneonta, through Morris, Edmeston, New Berlin, Sherburne, Garrettsville, West Burlington, Waterville and Deansboro, to Clinton, boulders were not seen in abundance except in the fields 2 miles northeast of Edmeston, and along Big creek between Waterville and Deansboro where they are washed out of what appears to be a stratified coarse gravel deposit. Two miles northeast of Edmeston a count of three hundred boulders along a fence on the ground moraine was made with the results shown in table 1, column 7. The local shale and gray and brownish gray sandstone, which break up into small flat pieces, were not included in the count.

At Clinton on the hill east of the town a count of boulders was made with the results shown in table 1, column 8. Two boulders of alkali syenite were also found here and there is little doubt that they both came from somewhere in the Monteregian hills. Here also the slabs of grayish and brownish fine grained sandstone and shale could not be counted on account of the way in which they break up into small pieces which really make up a large part of the surface deposit. So few boulders other than the Oneida conglomerate were seen that definite conclusions can hardly be drawn as to the relative abundance of the different kinds in making comparisons with other localities.

**Madison and Chenango counties.** Observations of very limited extent in Madison county and northern Chenango county did not result in finding any locality where boulders from distant sources were abundant enough to make possible an estimate of the percentages of the different kinds or to make it likely that boulders of many of the rarer kinds would be found. A few boulders of coarse gray anorthosite were noted in this region and one boulder of camptonite was found at New Woodstock. This scarcity of foreign boulders is in agreement with Brigham's description of the glacial deposits.

**St Lawrence Plain. Vicinity of Clayton and Alexandria Bay.** In the fields 10 miles south-southeast of Clayton boulders are abundant and many varieties from a large number of different sources are represented. The bed rock is Lowville limestone. A count of boulders above 1 foot in diameter in a length of 100 feet of wall gave the results shown in table 2, column 1. Other rocks of which

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one or more boulders were seen at this locality but not in this particular length of wall include essexite, tinguaite and camptonite from the Montereigan province and chlorite schist which is thought to be from the folded region of the eastern townships of Quebec. Several of the anorthosite boulders are of a reddish variety which is not known to occur in the Adirondacks. This color is not common in anorthosites but is like some parts of the Morin anorthosite to the north of Montreal, as shown by specimens in the Cornell University collections.

Counts of boulders were also made at two localities which are respectively 6 miles and 9 miles east-northeast of Clayton. The results are shown in table 2, column 2 and 3 respectively. Both of these counts were made on ground moraine. The close agreement of these two counts at two localities only three miles apart indicates that such counts really do approximate closely the relative abundance of boulders of the different rocks.

### Table 2
Counts of boulders in the St Lawrence valley

<table>
<thead>
<tr>
<th>LOCALITY NUMBER</th>
<th>1 ft</th>
<th>2 ft</th>
<th>3 ft</th>
<th>4 ft</th>
<th>5 ft</th>
<th>6 ft</th>
<th>7 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of boulders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number counted</td>
<td>152</td>
<td>140</td>
<td>142</td>
<td>169</td>
<td>203</td>
<td>66</td>
<td>288</td>
</tr>
</tbody>
</table>

Per cent of total number of boulders of each kind

- **Granite**: 16.4 15.8 8.4 8.9 18.2 28.8 14.3
- **Granitic gneisses**: 21.0 27.8 27.4 22.5 18.2 13.6 18.4
- **Grenville gneisses and schists**: 10.5 5.0 4.9 1.8 5.4 6.0 3.1
- **Amphibolite**: 4.0 0.7 1.4 2.3 4.4 ... 1.7
- **Gabbro**: 2.6 ... 1.8 1.5 4.5 0.3
- **Norite, foliated**: ... ... ... ... 3.3 ...
- **Diabase**: ... 2.2 1.4 1.8 ... ...
- **Anorthosite**: 13.8 0.7 0.7 11.2 4.4 25.7 ...
- **Graywacke**: 1.3 ... ... ... 5.9 ...
- **Milky quartz with chlorite**: ... ... ... ... 0.3 ...
- **Essexite**: ... ... ... ... 0.7 ...
- **Alkali syenite**: ... ... ... ... 1.7 ...
- **Camptonite**: ... ... ... ... 0.3 ...
- **Tinguaite**: ... ... ... ... 0.3 ...
- **Potsdam sandstone**: ... 30.2 53.3 55.6 9.5 33.0 6.0 34.4
- **Dolomite and sandy dolomite, Theresa, Tribes Hill, and Ogdensburg formations**: ... ... 40.3 14.3 12.1 17.7 ...

1 Ten miles south-southeast of Clayton, elevation 400; bed rock is Lowville limestone; boulders of it not counted.
2 Six miles east-northeast of Clayton, elevation 300; bed rock is Potsdam sandstone.
3 Nine miles east-northeast of Clayton, elevation 300; bed rock is Potsdam sandstone.
4 Seven miles southwest of Ogdensburg, elevation 300; bed rock is Theresa formation.
5 Two miles south of Ogdensburg, elevation 280 to 300; bed rock is Ogdensburg formation.
6 Five miles northeast of Ogdensburg, elevation 300; bed rock is Ogdensburg formation.
7 Ten miles east-southeast of Ogdensburg, elevation 340; bed rock is Tribes Hill formation.

Vicinity of Ogdensburg. A large number of boulders were examined near Ogdensburg and counts were made at four localities with the results shown in table 2, columns 4 to 7. The count 5 miles northeast of Ogdensburg is not strictly comparable with the others because only boulders of larger size (3 feet or more) were counted and the number counted was smaller. The most apparent variation other than those due to the change in the bed rock is the absence of anorthosite and the larger number of boulders of graywacke and Monteregian rocks at the locality farthest to the southeast of the river. A few boulders recognizable as from the Monteregian intrusives were found near where the count was made 5 miles northeast of Ogdensburg. These include two boulders of alnoite from Isle Cadieux or St Monique, Quebec, one boulder of sodalite syenite and others which will be mentioned in the section on petrography.

Petrography of Boulders

Only a few of the kinds of rock occurring as boulders have been selected for petrographic description. For the most part these belong to two classes: rocks whose known or probable source is limited to a comparatively small area, and rocks of unusual types with sources unknown. Boulders of the more common rocks, such as the Grenville gneisses, and the Precambrian granites and quartz syenites, are not described since these rocks have such a wide distribution in place that the source of any particular boulder can not be even approximately determined.

Anorthosite. Since these rocks are of very simple composition it will not be necessary to describe them at any length. In common with all anorthosite they consist chiefly of labradorite with small amounts of augite or hypersthene, or both, and occasionally a little magnetite and garnet. The different varieties occurring as boulders differ chiefly in the color of the feldspar and in the size of grain. The massive coarse to medium-grained varieties have light to dark gray or reddish brown feldspar, sometimes with greenish parts; the varieties with finely granulated feldspar are light greenish gray with dark streaks of pyroxene. All of these varieties occur rather abundantly as boulders in the vicinity of Clayton and Ogdensburg,
and much farther to the south near Ithaca, but boulders of the reddish anorthosite were not found either along the Mohawk valley or in the higher country to the south of it although the gray varieties are fairly common.

All or nearly all the anorthosite boulders of northern and western New York are believed to be from Quebec, and for the most part from the Morin anorthosite area north of Montreal. Ebenezer Emmons considered that the anorthosite boulders near the St Lawrence river and Lake Ontario must have come from some locality in Canada because these boulders are absent or very scarce along the west side of the Adirondacks in the area intervening between the Essex county anorthosite and the places where they are found abundantly. The Morin and Saguenay anorthosite areas were not known at that time.

**Gabbro.** Many varieties of gabbro and the closely related rock, diabase, were seen in boulders, but it was not found possible to assign any of these to definite sources, nor was it noticed that there was any difference in the kinds occurring in the drift at widely separated localities. The rather frequent occurrence of a variety in which the feldspar is colored an intense green by minute spinel inclusions is mentioned in passing. Varieties with a nearly uniform dark color are more common.

**Alkali syenite.** A boulder at Clinton is composed of a rather coarse-grained nearly white rock, containing as the principal mineral microperthite in thick tabular crystals up to 15 mm in greatest diameter. It is apparently about half untwinned feldspar and half albite with very fine twinning, but they are in a fine irregular intergrowth. Its refractive indices indicate that the untwinned feldspar is not pure orthoclase, but soda microcline (anorthoclase). There is about 5 per cent of oligoclase, and small amounts of aegerite-augite, greenish brown hornblende, magnetite, and apatite. In Professor Johannsen's quantitative modal classification it is a syenite with symbol 2210, near orthosyenite with symbol 229. It is similar to the "nordmarkite" of Shefford and Brome mountains, Quebec, described by Dresser and is believed to be from one or

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the other of these two mountains. Another boulder at the same locality resembles this one but differs slightly in that it contains 1 or 2 per cent of quartz, and that there is a coarser and more regular intergrowth of the feldspars in the microperthite.

A boulder of a rather coarse-grained light colored syenitic rock 10 miles east-southeast of Ogdensburg has the same mineral composition as the pulaskite of Mount Johnson, Quebec, but differs slightly in texture from the specimens of the Mount Johnson rock which have been seen by the writer, so the correlation can not be considered satisfactory. Its high content of feldspar, and the character of the accessory minerals place it with the Monteregian syenites rather than any of the Precambrian rocks.

**Nephelite-syenite.** A single boulder of nephelite-syenite was found 10 miles east-southeast of Ogdensburg. It is a light colored rock of medium grain and consists chiefly of orthoclase and nephelite with scarcely more than 5 per cent of aegerite-augite and small amounts of sphene, magnetite, and purple fluorite. The nephelite does not amount to more than 10 or 15 per cent of the rock. This boulder is not referable to any definite locality as source, but is evidently from the Monteregian Province and may be an extreme phase of the Brome Mountain nordmarkite, some parts of which contain a little nephelite.

**Sodalite syenite.** A boulder one foot in diameter, of a coarse-grained massive rock consisting of sodalite and alkali feldspars as the essential constituents was found 5 miles northeast of Ogdensburg. The feldspar is in flat tabular crystals up to 1 cm in diameter, and the sodalite, which is of a light bluish gray color, fills in the spaces between the feldspar, and is present in much smaller amount. Microscopic examination shows that the feldspar is microperthite and albite with the former in excess. The sodalite has a refractive index of 1.482, indicating that it is sodalite proper rather than some other mineral of the sodalite group. The estimated mineral composition of the rock is: alkali feldspars 70 per cent, sodalite 25 per cent, accessory constituents 5 per cent, including sphene, dark brown biotite, cancrinite, aegerite-augite, pyrite, and secondary calcite. In Johannsen’s classification it is 1118, leuco-albite-sodalite-syenite. If all of the soda feldspar were in separate crystals, there would probably be more albite than orthoclase and the rock would be classed as the corresponding variety of sodalite-syenodiorite rather than syenite. It seems probable that this boulder is from one of the Monteregian hills, but on account of the absence of nephelite it fails to agree with any of the published descriptions.
Essexite. In the description of the Monteregian hills the investigators extended the application of the name “essexite” to rocks differing greatly in mineral composition from those to which the name was originally applied. The Monteregian rocks which have been called essexite are of very diverse types, some approaching anorthosite, some theralite, and some pyroxenite, while the greater part of the rocks which have been classed as essexite are one variety or another of diorite or gabbro. In spite of the great differences in the total composition, however, there are all gradations from one variety to another, and there are certain peculiarities of texture and of the properties of certain minerals, such as the pyroxenes and amphiboles, which persist through a wide range of composition, so that it can not be denied that the extension of the name serves a useful purpose in showing the relationship of rocks which have a common origin and pass into each other by insensible degrees. In the discussion of the petrographic character of the boulders the name is therefore used in the same broad sense as it was used by O’Neill and others who have written on the petrography of the Monteregian hills.

The following points of difference are useful in distinguishing boulders of essexite from the Adirondack gabbros and other gabbros and norites of the Precambrian areas:

1. Complete absence of hypersthene and garnet from the essexite. The former is nearly always and the latter frequently present in the Precambrian gabbro.

2. The feldspar of the essexite is white or nearly so, and is free from small inclusions. That in the gabbro is full of small inclusions, which color it light to dark gray or greenish, and less often reddish or purplish.

3. The gabbro is often highly granulated and the minerals occur in bunches of very fine grain. The essexites sometimes show evidence of slight deformation subsequent to crystallization, in the wavy extinction of the feldspar crystals, but never show fine granulation like the gabbro.

4. Small to moderate amounts of feldspathoids (nephelite and sodalite) are present in much of the essexite, but never occur in the gabbro.

5. Apatite occurs more abundantly and in larger crystals in the essexite than in the gabbro.

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1 O'Neill, J. J. St Hilaire (Beloeil) and Rougemont Mountains, Quebec. Geol. Surv. of Canada Memoir 43, 1914. Contains bibliography on the Monteregian hills.
The most noticeable megascopic difference is the much lighter color of the essexite for the same amount of mafic constituents. This is due partly to the lighter color of the feldspar and partly to the coarser grain of the essexite.

The essexite boulders may be divided into two groups: (1) those in which the plagioclase is oligoclase to andesine, and, (2) those in which the plagioclase is labradorite to bytownite. It should not be understood, however, that all those in each of these classes are otherwise exactly alike, although on account of the small number of boulders found they naturally show less variation than does the rock in place. In all of these essexite boulders the feldspar makes up two-thirds or more of the rock so that the coarser varieties are rather light colored. Since boulders of yamaskite have been found and the varieties of essexite high in dark minerals are intermediate between yamaskite and the more feldspathic essexites, it is to be expected that some of the other varieties would be found, and they actually have been found around Ithaca where more thorough search for the rarer boulders has been made than in the areas dealt with particularly in this report.

The list of the essexite boulders found, with their probable sources, follows:

<table>
<thead>
<tr>
<th>Calcic variety with plagioclase labradorite to bytownite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localities of boulders</td>
</tr>
<tr>
<td>8 miles east of Ogdensburg</td>
</tr>
<tr>
<td>5 miles northeast of Ogdensburg</td>
</tr>
<tr>
<td>Sources</td>
</tr>
<tr>
<td>St Bruno or St Hilaire mountain, Quebec</td>
</tr>
<tr>
<td>Quebec</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sodic variety with plagioclase oligoclase to andesine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localities of boulders</td>
</tr>
<tr>
<td>10 miles south-southeast of Clayton</td>
</tr>
<tr>
<td>4 miles southwest of Canton</td>
</tr>
<tr>
<td>10 miles east-southeast of Ogdensburg</td>
</tr>
<tr>
<td>2 miles south of Schaghticoke</td>
</tr>
<tr>
<td>3 miles northeast of Amsterdam</td>
</tr>
<tr>
<td>Sources</td>
</tr>
<tr>
<td>Shefford mountain or Mount Johnson, Quebec</td>
</tr>
<tr>
<td>Shefford mountain or Mount Johnson, Quebec</td>
</tr>
<tr>
<td>Shefford mountain or Mount Johnson, Quebec</td>
</tr>
<tr>
<td>Shefford mountain or Mount Johnson, Quebec</td>
</tr>
<tr>
<td>Mount Johnson, Quebec</td>
</tr>
</tbody>
</table>

In Johannsen's classification the two boulders of essexite with the more calcic plagioclase would be 2316, or feldspathoid-bearing gabbro, since they contain a small amount of a mineral of the sodalite group. The essexite with the more sodic plagioclase would be 2216, or feldspathoid-bearing diorite, since they contain small amounts of either nephelite or sodalite, with oligoclase or andesine as the only feldspar.
The boulder from near Amsterdam in particular is very similar to the Mount Johnson essexite. On account of the occurrence of essexite in several of the Montréalian hills, and the variability of the rock in each of the hills where it does occur, it is not possible to state any more closely from which of the hills the boulders listed have come. Mount Royal can be eliminated as a source for these particular boulders because the essexite of it is all darker colored, and is often scarcely half feldspar.

Detailed petrographic descriptions of the boulders will not be given but it may be said that no essential difference could be found between them and the rocks of the Montréalian hills to which they are referred. The comparison was made with specimens in the case of Mount Johnson and Mount Royal only, the published reports on the others being used. The correlation is based not only on general similarity of appearance and composition of the rocks but also on the occurrence of like varieties of certain minerals and on agreement in the details of texture.

**Yamaskite.** This is a dark colored, medium to coarse-grained massive rock which contains augite as the principal constituent, with subordinate amounts of anorthite and sometimes olivine and ilmenite. The three boulders of this rock which were found in northern New York do not differ enough to require individual description. The localities are, respectively: 10 miles east-southeast of Ogdensburg, 8 miles east of Ogdensburg, and 3 miles southwest of Canton.

The estimated mineral composition of the boulder at the last mentioned locality is augite 75 per cent, olivine 10 per cent, bytownite 8 per cent, other minerals 7 per cent. It is a mela-calcigabbro, 3312, near 3412, since the plagioclase is near the anorthite end of bytownite. Strictly speaking this does not come within the definition of yamaskite given by Young,¹ who said the feldspar should be anorthite. Although he did not state the limit on the amount of albite which the plagioclase might contain and still be called anorthite, he probably placed it higher than the 5 per cent limit used here.

The augite in this rock is more coarsely crystalline than the other minerals, the grains averaging about 8 mm in diameter. In thin section the augite is slightly pleochroic from light brown or pinkish brown to light greenish yellow. Some of the crystals are twinned and some show zonal structure. The plagioclase is in small crystals compared with the augite and occurs in bunches of several crystals filling in the interstices between the augite. These appear as white

specks in the hand specimen. The olivine occurs in anhedral grains, and is partially altered to serpentine and a carbonate mineral. Small amounts of brown hornblende are present, usually surrounding the augite, but apparently as a magmatic mineral rather than as a later alteration product. Small amounts of magnetite or ilmenite, and pyrrhotite are present. There is no apatite observable in thin section.

These boulders check very well with the yamaskite of Mount Yamaska and Rougemont in southern Quebec, but are different from any rock which is known to occur in the Precambrian areas to the north. The analysis and description of essexite of St Bruno mountain\(^1\) suggest that some varieties of it may be similar to the yamaskites, but quantitative estimates of mineral composition are not available for the St Bruno rocks.

**Tinguaite, variety no. 1.** Boulders of tinguaite which agree exactly with occurrences of this rock in place in Montreal, were found at the following localities: 10 miles south-southeast of Clayton, 2½ miles south-southwest of Hammond (two boulders), and 5 miles northeast of Ogdensburg. The tinguaite of the one-foot boulder at the last named locality is selected for description because it is freest from alteration, but differs little otherwise from the boulders at the other localities.

This is a fine-grained greenish gray rock, with phenocrysts of oligoclase (near albite), sodalite, yellow sphene, and aegerite-augite, up to 2 or 3 mm in diameter. Phenocrysts are much subordinate to the groundmass, in which the minerals can only be recognized microscopically on account of the fine grain. The essential minerals of the rock are orthoclase, nephelite, aegerite, and oligoclase. Sphene, aegerite-augite, albite and a mineral of the sodalite group are present in small amount. The orthoclase, which is the most abundant mineral, occurs in relatively thick tabular crystals, mostly from 0.5 to 2.0 mm in greatest diameter, and incloses many short, stout hexagonal prisms of nephelite and long, slender aegerite crystals. The pyroxene phenocrysts are lighter green and have larger extinction angles than the smaller crystals and therefore contain less of the acmite molecule. In its texture and mineral composition this rock can not be distinguished from tinguaite specimens from Quick’s quarry in the city of Montreal. Its symbol is 22t8, corresponding to the plutonic rock nephelite syenite. It is far from the center point of both the order and the family, since the plagioclase

contains little more than 5 per cent of anorthite and the total feldspar is little more than 5 per cent plagioclase.

**Tinguaite, variety no. 2.** Another boulder of tinguaite of a different variety, which was found 5 miles northeast of Ogdensburg, has a mineral composition, by volume, estimated to be as follows:

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthoclase and microperthite</td>
<td>30%</td>
</tr>
<tr>
<td>Plagioclase, albite to oligoclase, many crystals zonal</td>
<td>30%</td>
</tr>
<tr>
<td>Sodalite</td>
<td>8%</td>
</tr>
<tr>
<td>Nephelite</td>
<td>10%</td>
</tr>
<tr>
<td>Aegerite</td>
<td>20%</td>
</tr>
<tr>
<td>Cancrinite</td>
<td>½%</td>
</tr>
<tr>
<td>Magnetite</td>
<td>½%</td>
</tr>
<tr>
<td>Pyrite</td>
<td>little</td>
</tr>
<tr>
<td>Sphene</td>
<td>little</td>
</tr>
</tbody>
</table>

Phenocrysts, which range up to about 6 mm in diameter, make up about 30 or 40 per cent of the rock. They are orthoclase, plagioclase, aegerite, white to faintly bluish sodalite, and pinkish nephelite. The texture is cumulophyric, that is, the phenocrysts occur in bunches rather than uniformly distributed. The groundmass with grains about 0.01 to 0.10 mm in diameter consists of potash feldspar, oligoclase and aegerite with very small amounts of the other minerals mentioned above. The aegerite occurs in irregular grains as well as in the slender prismatic crystals which are the more usual mode of occurrence in porphyritic rocks.

Nothing was found in the published descriptions which checks exactly with this boulder, but it is probably from one of the smaller of the Monteregian intrusive masses or perhaps a contact phase of one of the main syenite areas. It is similar to the nephelite-sodalite-syenite of St Hilaire mountain, described by J. J. O'Neill, but differs from it in that there is less sodalite and nephelite and no eudialite in the boulder. In Johannsen's classification it is near the boundary of 2219 and 2218, but probably in 2219 since there seems to be a slight excess of plagioclase over potash feldspar. It might therefore be called a sodalite-nephelite-syenodiorite.

**Tinguaite, variety no. 3.** A three-foot boulder of nephelite-free tinguaite was found 10 miles east-southeast of Ogdensburg. This is a porphyritic rock with light colored phenocrysts of orthoclase up to 10 mm in diameter, very sparingly distributed through a greenish gray groundmass made up mostly of grains from 0.1 to 1.0 mm in diameter. Microscopic examination shows that the phenocrysts contain some albite in perthitic intergrowth with the orthoclase but are not uniform in this respect, and that the groundmass con-

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1 O'Neill, J. J. *St Hilaire (Beloeil) and Rougemont Mountains, Quebec. Geol. Surv. of Canada. Memoir 43,* p. 38.
sists of oligoclase, orthoclase and aegerite, with small amounts of sodalite and astrophyllite. It was not possible to estimate accurately the relative amounts of orthoclase and oligoclase but there is somewhat less of the oligoclase than the potash feldspars, including microperthite. The rock is classified as 2214, or sodalite bearing syenite.

The aegerite is in slender prismatic crystals bounded by (110) and (100) with terminal faces lacking or poorly developed. The largest ones are about 1.0 by 0.2 mm but they are mostly much smaller. The optical orientation, $Z\alpha C=3^\circ$, strong pleochroism in green and yellow, and refractive index $\beta=1.79$ indicate that this pyroxene has a composition approaching closely that of the pure acmite molecule, $NaFe(SiO_3)_2$.

There is scarcely 1 per cent of the astrophyllite. Since the crystals of it are only a few tenths of a millimeter in diameter they are seen with difficulty in the hand specimen as specks of brown color and bright luster. In the thin section the astrophyllite is seen to occur scattered through the rock in single euhedral crystals and aggregates of several crystals. It has good cleavage in one direction, and extinction parallel to the cleavage and parallel to or symmetrical with the crystal faces indicates that it is orthorhombic. It is biaxial and positive, with $X$ perpendicular to the cleavage and $Y$ and $Z$ in the cleavage plane. All sections show some pleochroism, but it is strongest in those across the cleavage. The colors are $X$, orange-yellow, $Y$ slightly darker yellow than $Z$, and $Z$ pale lemon-yellow. The refractive indices are, $\alpha=1.68$ estimated from birefringence and $Y$, $\beta=1.700\pm0.004$, $Y=1.730\pm0.008$. The birefringence is about .050. These properties agree very satisfactorily with those of astrophyllite from other localities. Sphene which is so common an accessory mineral in alkali syenites and the related rocks, is entirely lacking in this rock, all of the titanium apparently having been used up in aegerite and astrophyllite.

Camptonite and monchiquite. These are considered as being the same rock since the distinction based on the existence of the partly glassy groundmass in monchiquite is an unimportant one and difficult to apply on account of the usual altered condition of this part of the rock. They all contain more than 50 per cent of mafites and therefore belong to class 3 of the quantitative modal classification. Specimens from two boulders of this general type of rock from 10 miles south-southeast of Clayton and 2½ miles southwest of Hammond, were studied microscopically.

The one from the latter locality shows very abundant black phenocrysts of augite and hornblende in a dark gray groundmass.
The largest crystals are about 1 cm in diameter, but they are mostly much smaller. Microscopic examination shows that there is about 50 per cent of augite, which is in idiomorphic crystals of all sizes from the largest phenocrysts down to nearly as small as can be distinguished with the microscope. The augite is slightly pleochroic from yellowish brown to purplish brown. There is about 10 per cent of brown hornblende which occurs only as phenocrysts. There is a small amount of biotite with dark rims. Small octahedra of magnetite are abundant. Around the dark minerals which are almost entirely in idiomorphic crystals there is a colorless material of low refractive index which is partly isotropic and partly weakly doubly refracting. This makes up nearly 30 per cent of the rock and is probably glass with some fine-grained nephelite or feldspar. Calcite is abundant as a secondary mineral in both the phenocrysts and groundmass. The rock can not be accurately classified because the nature of the leucocratic constituents is not known.

The other boulder differs from this one chiefly in that it contains no hornblende and more augite. It has some analcite in cavities with calcite. Neither these two nor any other boulders of these basic porphyritic rocks which the writer has found contain more than a very small amount of green augite such as Professor Kemp found very abundantly in the camptonite and monchiquite dikes of the Lake Champlain region. The augite is rather of a purplish to brownish color and pleochroic, corresponding to titanium augite. The most probable source for these boulders is regarded as being around Montreal, because dikes of these rocks are most abundant there. Similar rocks also occur around some of the other Montregian hills to the east of Montreal.

Professor B. K. Emerson has described boulders of a porphyritic rock of this general type, occurring on Canandaigua lake.

Alnoite. Two boulders of this rare rock, differing slightly from each other, were found about 5 miles northeast of Ogdensburg. The rock of the first boulder, which is the coarser grained, shows in the hand specimen poikilitic biotite crystals of dark brown color and bright luster, up to 8 mm in diameter. The rest of the rock is very finegrained and appears nearly black in mass.

2 Emerson, B. K. Note upon Two Boulders of a Very Basic Eruptive Rock from the West Shore of Canandaigua Lake; and their Contact Phenomena upon the Trenton Limestone. 46th Ann. Rep't N. Y. State Mus., p. 251-55, 1892.
In thin section the rock is seen to consist of olivine, melilite, biotite, and augite as the essential constituents, with a few per cent each of apatite, magnetite, and perofskite as accessory original minerals and small amounts of secondary calcite and bluish chlorite. In Johannsen's classification its symbol is 3125, or alnoite, since it contains between 50 and 95 per cent mafites, and the quarfeloids are all melilite.

The melilite is mostly not in distinct crystals because it was about the last thing to crystallize, but some crystals of it flattened parallel to (.001) occur as inclusions in the biotite.

The olivine is of two kinds, chrysolite or ordinary olivine, and monticellite, the Ca,Mg olivine, as in the alnoite at Isle Cadieux, which was described by N. L. Bowen. Considering the two kinds of olivine together they make up about one-half of the rock. The monticellite is distinguished from the chrysolite, which it closely resembles, by its negative optical character and lower double refraction. The monticellite occurs mostly in irregular grains, while the chrysolite is often in euhedral crystals, some of which have a partial or complete rim of monticellite in optical continuity with them.

The biotite is a faintly colored variety, in thin sections pale brown with a slightly greenish tinge. The crystals are of very irregular shape, are much larger than those of the other minerals, and are full of inclusions of olivine, perofskite etc.

The augite is light yellow in thin section. For the most part it has irregular boundaries. Several adjacent inclusions of augite in biotite have cleavage parallel, extinguish together, and have the same double refraction, indicating that they are similarly oriented although appearing entirely separated in the thin section. Bowen's interpretation of a similar structure in the Isle Cadieux alnoite is that it is due to the reaction of a residual liquid on the augite with formation of biotite during the later stages of the crystallization of the rock. The distribution of the augite in the rock is irregular but as nearly as can be estimated there is 5 to 10 per cent of it.

Both the magnetite and perofskite occur in small disseminated octahedra as primary minerals. Magnetite of secondary origin formed by the alteration of the chrysolite is also present. The apatite is in slender elongated crystals with basal parting. The presence of calcite indicates a moderate amount of alteration of the lime-bearing minerals, especially melilite, with which it is closely associated.

The other alnoite boulder from the same locality as the one just described is finer grained and fresher, showing an unusually small amount of alteration for a rock of this type. It also contains the poikilitic biotites in crystals up to 3 mm in diameter. It consists of chrysolite, melilite, biotite, magnetite and perofskite and has the symbol 3125. Monticellite may be present in small amount but was not positively identified. The biotite has a refractive index $\gamma = 1.610 \pm 0.005$ and the melilite $\omega = 1.640 \pm 0.005$, which check with the corresponding data on the minerals of the Isle Cadieux alnoite.

The boulder of augite-bearing monticellite alnoite agrees in all respects with a variety of the Isle Cadieux rock as described by Bowen. Not only are they alike in their unusual mineral composition, but the order of formation as indicated by the shapes and relationships of the crystals is the same for the two rocks. The corrosion of the augite crystals surrounded by biotite, and the rims of monticellite on chrysolite are especially characteristic. The finer grained boulder with slightly more simple mineral composition is similar to another variety of the Isle Cadieux alnoite, but is also like that described by Stansfield\(^1\) which occurs at St Monique, 25 miles to the north of Isle Cadieux. These two boulders are confidently regarded as having come from the immediate vicinity of one or the other of these two outcrops.

**Graywacke.** Certain boulders of fragmental rocks, showing evidence of dynamic metamorphism, are classed as graywacke rather than sandstone because of the large amount of chloritic and sericitic cementing material around the angular sand grains which indicates that the original sediment contained complex grains, probably of shale or slate, in addition to the grains of quartz and other pure minerals. As an example the rock of a two foot boulder 10 miles south-southeast of Clayton, will be described.

This is a greenish gray rock showing megascopically quartz grains up to to 2 or 3 mm in diameter in a fine slightly schistose matrix. Microscopic examination shows highly angular grains averaging about 0.5 mm in diameter. The fragmental material is about 80 per cent quartz and 20 per cent plagioclase. There are a few pieces of sphene, magnetite and graphite. The recrystallized matrix or cement is composed of calcite, chlorite and sericite. That the rock has suffered deformation is indicated by the parallel structure developed by the platy minerals and by the wavy extinction of many of the quartz and feldspar grains.

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Boulders of rocks similar to this were found wherever search was made in northern New York, as indicated on the map (figure 3). They were seen in greatest abundance about half way between Ogdensburg and Canton. These boulders are regarded as originating in the eastern townships of Quebec. Professor F. D. Adams has described under the name of feldspathic graywacke specimens from several localities in the eastern townships, which closely resemble these boulders in structure as well as in mineral composition. Geologic maps of this region are not sufficiently detailed to show the limits of distribution of the graywacke, but the belt of Cambrian rocks extending northeast on the west side of the Sutton mountain anticline is regarded as the most probable source of these boulders.

**Chlorite schist.** A boulder of chlorite schist 10 miles south-southeast of Clayton is a fine-grained green rock with poor cleavage. It has some small cavities stained with limonite. Microscopic examination shows that the average grain size is about 0.01 mm. The estimated mineral composition is chlorite 70 per cent, epidote 18 per cent, quartz 10 per cent, specular hematite 2 per cent.

Chlorite schist is reported by R. W. Ells as being one of the principal rocks of the Sutton mountain anticline in the eastern townships in southern Quebec. Some of the specimens of schistose rocks from the eastern townships, described by Professor F. D. Adams, are rich in chlorite, but contain also actinolite. Professor J. A. Bancroft also reports chlorite schist and mentions the occurrence in it of copper ore and veins containing milky quartz and siderite. While it is relatively narrow, the folded belt containing these rocks continues a long distance in the direction of strike and it might be expected that similar rocks should occur far to the south of the eastern townships along the same belt.

A boulder of milky quartz with fragments of fine-grained chlorite schist, and iron stained cavities where siderite has presumably weathered out, was found 10 miles southeast of Ogdensburg. A similar boulder of milky quartz with chlorite was found 3 miles south of Altamont. This contains also siderite, partly weathered to limonite, and a little chalcopyrite partly weathered to limonite and malachite. Several boulders of similar composition have been found in the vicinity of Ithaca, much farther from the belt of rocks where

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they are supposed to have originated. It is likely that the boulder at Altamont came from some locality farther to the south than those in northern New York and around Ithaca.

**Indications of Lines of Glacial Motion Based on Location of Boulders**

In general, the conclusions reached from the occurrence of boulders whose source is fairly well fixed do not conflict with the previously held ideas in regard to the direction of ice movement in New York and the adjacent parts of Canada and Vermont, nor do they make these ideas much more specific. A possible exception to this statement is discussed below in connection with the supposed eastern townships boulders.

The abundance of Canadian boulders in the Finger lakes region compared to farther east directly south of the Adirondacks, may be considered as evidence of the weakness of the ice current over the Adirondacks, and also as favoring the idea that little or no ice that came around the Adirondacks reached the region of Otsego county and the adjacent parts. Of course the absolute numbers of boulders of all kinds in these respective regions needs to be considered and, since boulders are much more abundant around the south ends of the Finger lakes than in the parts of Otsego county visited, it should be necessary to look at many more boulders in the latter area than has been done, before concluding that Canadian boulders are entirely absent.

The one essexite boulder near Amsterdam, believed to be from Mount Johnson, Quebec, should be especially noticed as being evidence that ice from somewhat east of north in southern Quebec, reached this locality. There is nothing to show whether it came nearly straight, or whether it followed the main valleys.

The boulders in the Hudson valley indicate southward movement along the valley, although little field work was done in this region. The very small number of recognizable Canadian boulders found near the Hudson suggests that the ice currents moving into the Hudson-Champlain valley from the north were comparatively weak, and that a large part of the ice which reached the vicinity of Albany, for example, was due to heavy precipitation in northeastern New York and northern Vermont. The scarcity of Canadian boulders may be more apparent than real, however, since in this region the Monteregeian rocks were the only ones of Canadian origin that we really hoped to distinguish from those from other localities.
That ice moved southwestward in the St Lawrence valley between Montreal and Lake Ontario is probably not disputed by anyone. Drumlins, the shapes of glacially eroded rocks, and glacial scratches all indicate this and the distribution of boulders checks it up in a general way, although over much of the part of northern New York that has been mapped geologically near the St Lawrence the bearing of the scratches is not so far west of south as the course of the valley itself, and as the line of motion indicated by the boulders. The occurrence in the vicinity of Clayton and Ogdensburg, of boulders of chlorite schist and greenish graywacke or feldspathic sandstone from the Sutton mountain range of the eastern townships of Quebec, brings up the interesting question of to what extent continental glaciation was effective in southern Quebec, and especially the eastern townships region north of Vermont. That these boulders actually came from the eastern townships would seem to be indicated by the fact that not only they, but also boulders from some of the more easterly ones of the Montereigian hills become more abundant 8 or 10 miles southeast of the St Lawrence in the vicinity of Ogdensburg than within a mile or two of the river, and that there is a corresponding decrease in boulders derived from north of the St Lawrence, especially anorthosite boulders.

According to R. W. Ells¹ any glaciation of which evidence remains in the eastern townships, or rather more particularly the region about Sutton mountain, was of a purely local nature, and the direction of motion was northwest as indicated by scratches and by boulders of serpentine and diorite from Orford mountain. Ells lays stress upon the control of ice movement by topographic features in this local glaciation, especially in the valley of St Francis River. It seems reasonable to suppose that the Sutton mountain range with a maximum elevation of about 3000 feet supported local glaciers after the ice in the lower part of the St Lawrence valley had entirely melted or had become so thin that it would not move much. Ells, however, states that in this area he could find no evidence that it had ever been covered by a continental ice sheet. For the country farther to the east Chalmers² is even more explicit in referring all of the glacial phenomena to local glaciers moving northward on the slope toward the St Lawrence.

The ice perhaps moved northwest from the higher part of the eastern townships during a large part of the glacial period, and may have encountered at some stage relatively stagnant ice in the St Lawrence valley which had either accumulated in place from snowfall or had come from the Laurentian highlands a short distance to the north. Under such conditions boulders from the eastern townships might easily have become incorporated in the ice in the valley at some distance above the bottom by pushing of the ice from one direction over that from the other. Then at some later stage in the ice age when the ice was thicker the boulders which had already been carried a short distance to the northwest would have been carried much farther to the southwest by ice from the Laurentian highlands, and ice accumulated in place moving up the St Lawrence valley, and spreading out into the valley of Lake Ontario and the country to the south.

On the other hand, it seems barely possible that previous to the development of local glaciers in the eastern townships, at least the west side of the Sutton mountain range was covered by ice which was a part of the Labradorian ice sheet and which was moving somewhat west of south.

Anorthosite boulders are not so numerous as might be expected in the Mohawk valley, in the Helderberg mountains, or the northeastern part of the southwestern plateau physiographic province. The boulders which do occur in these areas are from the main area of anorthosite in the eastern Adirondacks. Somewhere in central New York the boulder train from the Morin anorthosite overlaps that from the Adirondacks. Most of the anorthosite boulders in northern and western New York are believed to be from the Morin area north of Montreal, but some may be from still more distant sources. As far as the distribution of the boulders of the Morin anorthosite is known, they indicate a direction of movement from southwest to south-southwest from the source, essentially in agreement with the other data, but the limits of the boulder train from this source have not been mapped. The anorthosites are all so much alike that it is usually difficult to tell from the petrographic character of a boulder, from which area it is derived.

Limits of Distribution of Boulders of Particular Kinds of Rock

It was hoped to be able to show and discuss in some detail the areal distribution of boulders of a few rocks the limits of whose possible sources are well known. The information available is still so incomplete, however, that it is considered best to wait until more
is known as to the occurrence of boulders between the sources and the localities where they were found by the writer. Mount Johnson in southern Quebec would appear to be an eminently suitable one from which to study the dispersal of boulders, on account of its small area and the easily recognizable character of the rocks which compose it.

**Boulders as Evidence of Glacial Erosion**

Distant transport of boulders from a very small source and their distribution over a large area even though very scarce is an evidence that a large amount of erosion must have been caused by the glacier. A knowledge of the size and frequency of occurrence of the particular kind of boulders in the different parts of the area in which they occur would furnish a basis for an approximate estimate of the actual amount of material removed, but of course it would be difficult to estimate the total amount of the rock in the glacial deposit even if the amount on the surface were known with a fair degree of accuracy.

**General Conclusions and Evaluation of Results**

Enough work has not yet been done in the northeastern United States thoroughly to test out the possibilities of the study of boulder dispersal as a part of the science of glacial geology. As the bed rock formations from which the boulders are derived become better known and detailed maps of glacial deposits are made for more areas, the conditions for boulder investigation will be greatly improved. On account of the large areas under consideration and the difficulty of one person being familiar with all classes of rocks which are found as boulders, contributions on this subject may necessarily be fragmentary. If it seems that from one month's field work we have obtained little in the way of positive results, this does not necessarily indicate that by these methods valuable contributions may not be made to glacial geology, but rather that more extensive and perhaps more detailed field observations will need to be made and interpreted. By the correlation of observations by different persons on boulders at different localities perhaps more could be accomplished than by one person attempting to study directly all of a large area.

Little has yet been done in New York toward a study of the composition and sources of the morainic deposits although much has been done in the mapping of glacial deposits from their external form and general structure. Where boulders are abundant a determination of the kinds present may be considered a contribution to
regional petrography and mineralogy. Knowledge of the occurrence of boulders of rocks or minerals far from where they are found in place should be of value to students of mineralogy and petrography in this State. Location and description of boulders of types for which no probable source can be found may lead to the discovery of masses of these rocks which have been overlooked or which occur in unmapped regions. In addition to the study of boulders as a means of determination of the directions of glacial motion, other lines of research on glacial boulders were suggested either by this work or the reading in connection with the preparation of this report; some of these will be specifically mentioned, without claiming that any of them involve new ideas.

It might be of interest to make a quantitative study of the composition of the ground moraine, recessional moraines and other glacial deposits in the same region. In some instances the differences between the kinds of boulders in these different types of deposits have been remarked upon in a general way but it is thought that a more exact study would add greatly to our knowledge of glacial erosion and of the way in which material is carried by the ice.

The vertical distribution of materials from different sources in sections of morainic deposits may be worthy of further investigation. Sauramo reports that in some of the moraines in Finland the boulders of the different rocks from the bottom to the top of the section are in a general way in the same order as their respective sources, as one goes back in the direction from which the ice came. If there is a tendency for the boulders to be so arranged, we might expect that there would be more mixing of the upper and lower parts at many other places than in the part of Finland referred to, where the relief is comparatively low.

It seems to the writer that there is more to be done in the study of the shapes of boulders, in relation to the kind of deposit, the position in the deposit, the kind of rock of which the boulder is composed, and the distance of the boulder from the source. More detailed investigation of the variation in size of boulders with distance from the source is also suggested in this connection.

Renewed attention is attracted to glacial boulders as an aid in prospecting by the recent work in northern Europe which has been reviewed by Sauramo. If the conditions for the examination of boulders were as favorable as in Finland, it is believed that glacial boulders would be of great value in prospecting in northern Ontario.

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and Quebec. Under present conditions, however, boulders can only be examined readily in thoroughly burned areas and along river banks.

The transported boulders and smaller fragments of fossiliferous rocks which are found throughout practically all of New York would need to be investigated by a paleontologist familiar with the Paleozoic of New York and southern Canada. Brigham\(^1\) investigated the boulders of sedimentary rocks between the Mohawk and Susquehanna rivers, but only considered the dispersal of boulders from a definite ledge in the case of the Oriskany sandstone at Oriskany Falls.

**Summary**

Field work of about a month in central and northern New York followed by laboratory examination of specimens collected and searching of the literature, has resulted in finding only a few boulders and those all from the Monteregian province, for which the source could be located within a few miles or less; for some others, as the anorthosites of the Adirondack and Morin areas and the graywacke and chlorite schist of the eastern townships, the general region of the source can be pointed out; while still others, such as many of the granites and gneisses, may have come from any one of a number of very widely separated areas, some of which are of large size. Petrographic descriptions of some of the boulders are given and attention is called to the Monteregian hills as sources from which boulders may be traced. So far the indications as to directions of glacial motion derived by the writer from boulder dispersal are general and suggestive rather than specific and demonstrative.

MODERN IDEAS ON AMERICAN STRATIGRAPHY AND PALEOGEOGRAPHY

by Dr. Gustaf T. Troedsson

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It is certainly not a mere accident that the present high status of the American stratigraphy is contemporaneous with the mining of the immense natural products in the sedimentary formations of America. The wide distribution of the sediments, the easily accessible sections, the large scale mining of natural products, the numberless drillings, etc., have furnished American geologists with an abundance of observations, beyond comparison in any other country of the world. Furthermore the absence of national boundaries in America allows anybody to study the main features of a large continent of rather simple structure, “the type continent” of Dana, while the European geologist has to rely mainly upon his own national part of the broken European borderland of the Eurasian continent.

In fact it is no wonder that America having these advantages has become the leading country in stratigraphy as well as in paleogeography. A paleontologist from a country upon the Fennoscandian Shield — like the present writer — will of course be pleased to feel the obvious interest shown in Scandinavian stratigraphy in America, particularly by the State Geological Surveys. But this is as logical as the fact that America has produced the founders of modern paleogeography.

It is true, however, that the modern American views have been very little followed in Europe. This is perhaps due to the science itself; the results attained by a geologist are not in the same degree applicable in other parts of the world as in the case of most branches of natural science. Therefore, new ideas in geology need a long time to get through. For the time immediately behind us we have also to take into consideration the isolating period of the World War. In spite of this the scientific connections across the Atlantic ocean are not what they could be or ought to be.

This is the reason why I have tried to give a brief account of the principles now ruling in American stratigraphy and paleogeography, mainly by aid of experiences from a journey through the eastern and some other parts of the United States from July 1921 to January 1922. During this travel, for which I am deeply indebted to the American-Scandinavian Foundation, I had the
invaluable favor of being guided in the field and the museums by several of the leading geologists and paleontologists of America to whom I desire to express my thanks. Above all I wish to mention Professors Schuchert of Yale and Raymond of Harvard, Doctors Ulrich and Bassler of the National Museum, Washington, D. C., Doctors A. F. Foerste, Dayton, Ohio, R. Ruedemann, Albany, N. Y., and J. A. Udden, Austin, Texas.

This paper was originally written and printed in Swedish1 in order to draw attention to those ideas that seem to be of special interest to our own stratigraphy. In translating the paper into English I have summarized the reviewing part but added some notes on Swedish geology.

In the year 1902 the first fundamental principles concerning American paleogeography were established by Ulrich and Schuchert in “Paleozoic Seas and Barriers in Eastern North America,” a paper, prepared and printed for the annual report of Director John M. Clarke, and at his request. These principles have been developed further by the same authors, to some degree in diverse directions. The important papers published by T. C. Chamberlin, Schuchert, Ulrich, Willis,2 and others, on diastrophism and paleogeography in the years around 1910, show us that entirely new paleogeographic and stratigraphic methods, foreign to European science, had begun to develop and have in part been accepted.

Among the most noteworthy of these papers are Ulrich’s Revision of the Paleozoic Systems and Schuchert’s Paleogeography of North America. These complete each other exceedingly well and give a good idea of the actual problems in American historical geology of today.

As alluded to above, there is perhaps no science where the opinions are so diverse as in geology, depending upon the kind of facts and methods bearing on this science, the different kinds of experience of students, as well as the great difficulty of getting experience wide enough to form a judgment on every question. Concerning

2 Chamberlin, T. C. Diastrophism as the ultimate basis of correlation. Jour. Geol. v. XVII. Chicago 1909.
especially the Lower Paleozoic formations, we know that they have their most complete development in the Eastern United States. Therefore, the interest devoted to American stratigraphy by stratigraphers in other parts of the world will, of course, be attractive to students with especially wide knowledge in this field. Ulrich's Revision is founded upon an immense first-hand experience. But we have also to bear in mind that this experience has been procured from a limited part of the world; the universality of the ideas and theories met with in the Revision has not yet been proved; this concerns above all Ulrich's revised classification.

The discovery of breaks in apparently complete successions has given us a new fundamental criterion in stratigraphy. But it is a method that has to be used with discretion. It has shown its scientific value through numberless observations in America by many stratigraphers. And there is perhaps nobody who has given such prominence to it as Ulrich, when stating that "the accessible depositional sequence at whatever locality and however obscure the breaks, is always incomplete. The more complete the stratigraphic record the more numerous the hiatuses; the fewer the breaks the greater their average time values." Already the first stratigraphers in England have indicated hiatuses between the systems and in the rest of Europe we know many breaks of this kind. The ruling opinion is, however, that breaks are angular unconformities or at least indicated by basal conglomerates. Neither in Scandinavia nor in Germany is there any single name for disconformity. "Diskordans" is always angular, "konkordans" is a simple contact without hiatus. During recent years the idea of conformable hiatuses has obtained increasing attention through the influence of the American science. During my travel in the United States I had occasion to visit some of the most familiar localities, for instance those at Waldron, Ind., Louisville, Ky., and Buffalo, N. Y. Concerning the disconformity between the Silurian and the Devonian coral limestones at Beargrass quarry at Louisville I must admit that it would have escaped my attention entirely, if I had not known about it beforehand. And yet important parts of the Silurian and Devonian are there lacking.

Ever since the important erosional power of mountain streams has been generally recognized, the students of geology and physical geography have been inclined to overestimate the amount of erosion in general. Contrary to this, Ulrich maintains a distinction between

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the erosion in positive and negative areas. I should be inclined to suggest that Ulrich has really been one of the first to prove the possibility of nonerosion in negative areas. An illustration like the Fernvale, a thin Ordovician limestone formation, that has remained practically intact through whole geological periods, ought to become impressed on the mind as well as the well-known transporting powers of the mountain rivers. The theory of slight erosion constitutes a key to modern paleogeography: for areas without deposits during a certain period are normally looked upon as land areas.

The oldest stratigraphic criterion the fauna, has been much disputed. On the one hand, Ulrich has restricted its original dominant character in stratigraphy; on the other, however, it has gained more importance in paleogeography. As a rule a hiatus is indicated by a marked faunal break. This, again, is caused by the fact that the four seas around North America have given rise to as many faunal realms: the transgression from one sea with its fauna has succeeded a transgression from another sea with an entirely different fauna. Repeated transgressions from one realm, or recurrent faunas, are often, but not always, intercalated with beds carrying fossils from another realm, on account of the tilting of the continent. The most striking case of recurrence is the Spergen Hill fauna which appears four or perhaps six times within one or two periods (Ulrich). There are probably few things, however, which have caused more discussion in geology than the recurrent faunas. It would carry us too far to review the different opinions. Ulrich, for instance, denies entirely the possibility of different faunas in the same Paleozoic basin, thus rejecting the common view ruling among geologists since Forbes' studies of the distribution of the recent fauna along the coasts of Great Britain. I wonder if not still more detailed studies of the recent bottom fauna in the ocean coast regions would let us learn the real relation between the different faunal assemblages. Such studies have been made in late years by Swedish and Danish zoologists in the Skagerrack, the Cattegat, the Sound and in the Baltic sea. The distribution of the bottom fauna in these regions depends mainly upon depth, temperature and other physical conditions of the water but very little upon the bottom material. The different faunal provinces form narrow or broad bands along the coast and a central zone with the animals of the deepest water. Every zone has distinct leading or index forms; sometimes two stations a few hundred feet apart do not show any species in common. The zones of the Baltic sea are very few and correspond to the shore zones of the more open waters of the Cattegat and Skagerrack.
Because most of these results have not yet been published I cannot go further into detail. Whether these facts will affect the theory of recurrence it is not yet possible to determine.

The possibility of recurrent faunas renders the faunistic correlations much more uncertain. Ulrich claims, however, that every recurrence has brought about new variations in the organisms and these variations can also be recognized but only by the most careful discrimination in the study of the fossils. “If paleontological correlations have sometimes proved erroneous or imperfect, the fault has not lain with the fossils, but with the paleontologist who endeavored to interpret their testimony. Studied in minutest detail and determined and matched as critically as possible, the fossils tell the story both truly and fully.”

It is evident, however, that this method demands much of the paleontologist and, as a rule, it will not give absolute clearness in difficult questions. Ulrich also lays much stress upon physical evidence, for instance the presence of disconformities etc., and, above all, diastrophic criteria are decisive according to him; “Diastrophism, in its broadest sense, affords the only means of finally attaining a reasonably accurate and systematically constructed classification.”

The theory of diastrophism had its origin in Europe, it is true, but in America it has been developed to a stratigraphic criterion, thanks to works by Willis, Chamberlin, Ulrich, and others. Recently it has, however, been severely criticized by Shepard. Diastrophism as a stratigraphic criterion is founded upon the idea of permanency as to the distribution of the positive and negative elements of a continent. These are conditions closely connected with paleogeography, as it has been elaborated by Ulrich and Schuchert. And because their methods of paleogeography have been very little tried in Europe, the question of diastrophism has not gained much attention except in connection with the theory of great crustal movements.

The above mentioned stratigraphic criteria afford the main basis for modern paleogeography. The paleogeographic maps published by Schuchert, Ulrich, and Willis are indeed very different, at least in details. This is, however, not remarkable because of the different

stress laid upon different premises. Ulrich, for instance, pays more attention to the diastrophic movements than do geologists in general. We have also to bear in mind that the paleogeography is still in its early development, and we have to reckon with its eminently uncertain character, but in spite of this the results hitherto obtained give excellent promise for the future. After the publication of Seas and Barriers, the next important step forward in paleogeography is marked by Schuchert's eminent work Paleogeography of North America,\(^7\) which apparently belongs to those American geological papers of recent time that have received attention in Europe. Finally, Schuchert has by his Sites and Nature of North American Geosynclines given paleogeography a central place in modern geology.

It is not at all the intention of the writer to take a definite position with reference to the discussion of these questions now going on in America. For us in Europe the matter is rather how to direct attention to the possibilities which eventually are to be found in the views of the stratigraphical problems that have gradually been advanced in America. In America where disconformities, stratigraphic overlaps, recurrent faunas, etc. are well-known facts, the main debate deals with the interpretation of the individual cases, thus being on another level than in Europe where most geologists do not yet take all these criteria into consideration. Again it is evident that bringing these new methods to Europe will furnish new proofs for or against them, and thus help to solve one of the most difficult problems in geology: the reconstruction of the ancient continents.

In deciding how to apply the above-mentioned ideas in stratigraphy and paleogeography to studies in other parts of the world, I believe that a region like the Scandinavian-Baltic part of Europe ought to become eminently valuable for comparisons. The Lower Paleozoic of this region belongs to the most thoroughly studied series of strata in the world and, furthermore, this part of Europe shows in its main tectonic features great similarities to America: it has a nucleus of Archean (Fennoscandia) surrounded by Paleozoic and younger beds. The value of comparison with this region has early been recognized in America. Thus, Bassler\(^8\) has studied the Baltic

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\(^7\) Bul. Geol. Soc. America, v. 34, 1923. Presidential address.
Paleozoic Bryozoa. Raymond,\(^9\) Twenhofel,\(^10\) and Grabau\(^11\) have visited the region and published their opinions of the stratigraphy with comparisons with America (1916), and finally Ulrich and Ruedemann have travelled through some of the main Paleozoic districts of Sweden (1922). Most of our literature, however, is evidently not accessible to the majority of students because it is principally written in Scandinavian languages.\(^12\)

The main features of the Fennoscandian region have already been shown to American readers by the Norwegian geologist O. Holte
dahl.\(^13\) From Scotland the Caledonian Geosyncline extended during Cambro-Silurian time along the western part of the Scandinavian peninsula, Spitsbergen, and the northernmost part of Greenland. To the west of this geosyncline lay an unstable Atlantic land-area, to the east the stable Archean region, the Baltic shield, the most positive part of which was Finland. I should rather suggest that this positive region extended to the southern end of the present Sweden; but this southern part was divided into smaller ones by troughs running E–W or, farther to the south, SE–NW. It has been recorded in recent years that some synclines with Cambro-Silurian remains in eastern South Sweden as well as the surrounding horsts were established already in Subjotnian (early Algonkian) time.\(^14\) Even the details in fracturing, such as the breaking up of the anticlines into smaller segments, were worked out in Subjotnian time. And even more these segments are still easily recognizable; they have of course been eroded on their surfaces, but the summit of each segment forms an even plain which is part of the Subjotnian land surface. This land surface is about the same as that of Subcambrian age; as a common name the “Precambrian landsurface” has been proposed. In the Subjotnian syncline of Östergötland—

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\(^12\) The Paleozoic formations of Sweden are treated by J. C. Moberg in Historical-Stratigraphical review of the Silurian of Sweden. Sveriges geol. unders. Ser. C. Nr. 229. Stockholm 1911. This book contains also the main bibliography on the subject up to 1910.


\(^14\) Asklund, B. Bruchspaltenbildungen im südöstlichen Östergötland nebst einer Übersicht der geologischen Stellung der Bruchspalten Südostschwedens. Geol. För. i Sthlm Förh. 1923.
as well as in other regions with Cambro-Silurian deposits—the sedimentary rocks have been removed by erosion from great areas. Their originally wide extent is indicated by the appearance of Cambrian sandstone dykes. In such areas the Archean surface of today is even and identical with that below the Lower Cambrian sandstone. Högboom\textsuperscript{15} has shown that the average Post-Silurian erosion of these parts of the Sub cambrian crystalline ground has hardly surpassed a few meters of thickness of rock.

The Lower Paleozoic transgressions in South Sweden have come partly from the west, partly from the east; and several of the eastern transgressions, which have not always reached the western provinces, have extended from the north far to the south into the geosyncline and left deposits in northern Sweden and southern Norway. The western transgressions again have invaded the geosyncline from the south and, as a rule, not reached beyond the Baltic region.

In recording the different transgressions I can not go far into detail.

At Hardeberga, near Lund, province of Scania, the most complete Lower Cambrian succession in Scandinavia has been recorded. Nevertheless there are at least two breaks in the uppermost layers, none of which corresponds to the boundary between Lower and Middle Cambrian. The section is from above down:

1 Alum shale belonging to Middle Cambrian.
2 Calcareous and argillaceous sandstone
3 Highly calcareous sandstone with basal phosphatic conglomerate
   Zone of \textit{Acrothel a bellapunctata} Walcott
   Disconformity (sharp and clear)
4 Limestone of shell fragments
5 Calcareous sandstone with well-worn large quartz grains; pebbles of phosphatic sandstone, sometimes more than 50 mm in diameter, in the basal layers
   Zone of \textit{Ellipsocephalus} and \textit{Strenuella}
   Disconformity
6 Fine-grained sandstone. A few meters down in this sandstone the zone of \textit{Schmidt iell us Torelli} Moberg, \textit{Hyolith us De Geeri} Holm, and \textit{Obolella Mober gi} Walcott have been found.

A still older zone, that of Discinella Holsti, has not yet been met with in Scania. This is the oldest Scandinavian fossil-bearing horizon and has been recorded in the Mjösen district of Norway and in the Baltic region.

It is probable that the above-mentioned transgressions have come from the east, or from the north in Norway, and there are no positive facts for any marine connection between Scandia and England in Lower Cambrian time. This condition ruled perhaps during the oldest Middle Cambrian time (zone of Paradoxides ölandicus). But then the western transgressions became dominant during Middle and Upper Cambrian (Paradoxides and Olenus shales) and Lower Ordovician time. The Dictyograptus fauna invaded this region from the west and so did the Ceratopyge fauna. The latter was, according to Grabau¹⁶ of Siberian or Pacific origin. This might be right, but a few forms have ancestors in the Swedish Upper Cambrian and there is good evidence for this fauna having entered at least the south Scandinavian area from the west; we have for instance to remember its wide distribution in western Europe and the more complete development of the transgressing part of the Ceratopyge shales in the Oslo district of Norway than in Sweden. The remaining Ordovician succession has occasioned much trouble. There are shales with graptolites in Scania and in regions bounding the Caledonian geosyncline, while limestones predominate in the main Ordovician districts of Sweden. These limestones are closely connected with the Ordovician series in Esthonia; the shales, however, correspond exceedingly well with the English Ordovician. The ruling theory is that these shales and limestones have been laid down in one continuous basin. But in many cases it has been impossible to correlate the beds. The introduction by Raymond, Grabau, and others, of the hiatus element into the Baltic-Scandinavian succession has no doubt shown how to solve the problems. I am convinced that future field work will prove the presence of disconformities in many places where faunal breaks long have been known. Of remarkable hiatuses there is for instance the one embracing most of the Middle and Upper Cambrian in the Baltic provinces, the widespread but not yet recorded in all Scandinavia Cambro-Ordovician disconformity, probably corresponding to the Ozarkian formation of America, the disconformity between the Chasmos and the Trinucleus beds, etc.

Recurrent faunas have probably also been found. The Leptaena limestone of Dalarne has, on account of its fauna which shows

much resemblance to that of the Borkholm beds of Esthonia, been placed at the top of the Ordovician (Richmond), above the Trinucleus shale. In recent years, however, observations have been made which suggest a position below this shale and even a disconformity between the limestone reefs and the Trinucleus shale above them. If this be right the Leptaena limestone is to be looked upon as a reef facies in the Chasmops limestone. Such a position would indeed correspond better with the place given by English stratigraphers to the Kildare and Keisley limestones in Great Britain and Ireland.

Many problems could be mentioned which remain unsolved in spite of good observations and which seem to be explained rather well only if we assume the presence of disconformities and the possibility of recurrences. Since we now know that there are disconformities in our sections we have to look out for them still more. This will perhaps bring our Lower Paleozoic series into better accord-ance with that of North America. And above all it will afford a safe basis for paleogeography.
New York State Museum
JOHN M. CLARKE, Director

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1906. 186p. 41pl. 25c.
1907. (Bui. 121) 212p. 63pl. 50c.
1908. (Bui. 133) 334p. 39pl. map. 40c.
1910. (Bui. 149) 280p. il. 42pl. 50c.
1911. (Bui. 158) 218p. 49pl. 50c.
1912. (Bui. 162) 214p. 50pl. 50c.
1913. (Bui. 173) 158p. il. 29pl. 40c.
1914. (Bui. 177) 174p. il. 33pl. 45c.
1915. (Bui. 187) 192p. il. 56pl. 5 maps. Out of print.
1916. (Bui. 196) 308p. il. 50pl. maps. 55c.
1917. (Bui. 207, 208) 211p. il. maps. 75c.
1918. (Bui. 219, 220) 303p. il. 43pl. 75c.
1919. (Bui. 227, 228) 140p. il. maps 50c.
1922. (Bui. 251) 221p. il. 50pl. map. Out of print.
1923. (Bui. 253) 136p. il., 7pl. 50c.
1924. (Bui. 260) 127p. il., June 1925

These reports cover the reports of the State Geologist and of the State Paleontologist, Bound also with the museum reports of which they form a part.

Geologist's annual reports 1881-date. Rep's 1, 3-13, 17-date, 8vo.; 2, 14-16, 4to.

In 1868 the paleontologic work of the State was made distinct from the geologic and was reported separately from 1869-1903. The two departments were reunited in 1904, and are now reported in the Director's report.

The annual reports of the original Natural History Survey, 1837-41, are out of print.

Reports 3-4, 1881-84, were published only in separate form. Of the 5th report 4 pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and 47th museum reports.

Separate volumes of the following only are available.

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Paleontologist's annual reports 1899-date.

See first note under Geologist's annual reports.

Bound also with museum reports of which they form a part. Reports for 1899 and 1900 may be had for 20c each. Those for 1901-3 were issued as bulletins. In 1904 combined with the Director's report.

Entomologist's annual reports on the injurious and other insects of the State of New York 1882-date.

Reports 3-20 bound also with museum reports 40-46, 48-58 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3-4, 17 are out of print, other reports with prices are:

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M198r-024-5000 (2430)
Reports 2, 8-12 may also be obtained bound in cloth at 25c each in addition to the price given above.

Botanist's annual reports 1867-date.
Bound also with museum reports 21-71 of which they form a part; the first Botanist's report appeared in the 21st museum report and is numbered 21. Reports 21-24, 29, 31-41 were not published separately.
Separate reports for 1871-74, 1876, 1888-99 are out of print. Report for 1900 may be had for 50c. Since 1901 these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have also been published in volumes 1 and 3 of the 48th (1894) museum report and in volume 1 of the 49th (1895), 51st (1897), 52d (1898), 54th (1900), 55th (1901), in volume 4 of the 56th (1902), in volume 2 of the 57th (1903), in volume 4 of the 58th (1904), in volume 2 of the 59th (1905), in volume 1 of the 60th (1906), in volume 2 of the 61st (1907), 62d (1908), 63d (1909), 64th (1910), 65th (1911), v. 2 of the 66th (1912) reports. The descriptions and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and, combined with others more recently prepared, constitute Museum Memoir 4.

Museum bulletins 1887-date. 8vo. (1) geology, economic geology, paleontology, mineralogy; (2) general zoology, archaeology, miscellaneous; (3) botany; (4) entomology.

Bulletins are grouped in the list on the following pages according to divisions.
The divisions to which bulletins belong are as follows:

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BULLETIN

Clarke, J. M.; Simpson, G. B. & Loomis, F. B. Paleontologic Papers


Cumings, E. R. Lower Silurian System of Eastern Montgomery County; 34

Merrill, F. J. H. Guide to the Study of the Geological Collections of

194 Entomology

Director's report for 1916

196 Director's report for 1915

198 Botany

199 Economic Geology

200 Entomology

201 Economic Geology

202 Entomology

203-204 Economic Geology

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207-208 Director's report for

197 Geology

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219 Paleontology

220-222 Paleontology

223-224 Economic Geology

225-226 Geology

227-228 Director's report for

199 Geology

229-230 Geology

231-232 Entomology

234 Economic geology

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The figures at the beginning of each entry in the following list indicate its number as a museum bulletin.


Contents: Clarke, J. M. A Remarkable Occurrence of Orthoceras in the Oneonta Beds of the Chenango Valley, N. Y.

Parapomona cryptophyta; a Peculiar Echinoderm from the Interventricular Portage Bed of Western New York.

— Dictyonine Hexactinellid Sponges from the Upper Devonic of New York.


Loomis, F. B. Siluric Fungi from Western New York.
NEW YORK STATE MUSEUM

Contents:


Contents: Ruedemann, Rudolf. Trenton Conglomerate of Rysedorph Hill.
Clarke, J. M. Limestones of Central and Western New York Interbedded with Bituminous Shales of the Marcellus Stage.
Clarke, J. M. New Agelacrinites.
— Value of Amnigenia as an Indicator of Fresh-water Deposits during the Devonic of New York, Ireland and the Rhineland.


15. — Ancient Water Levels of the Champlain and Hudson Valleys. 206p. il. 11pl. 18 maps. July 1905. 45c.


Hartnagel, C. A. Stratigraphic Relations of the Oneida Conglomerate.
— Upper Siluric and Lower Devonic Formations of the Skunnemunk Mountain Region.
Whitlock, H. P. Minerals from Lyon Mountain, Clinton Co.
Hudson, G. H. On Some Pelmatozoa from the Chazy Limestone of New York.
Clarke, J. M. Some New Devonic Fossils.
— An Interesting Style of Sand-filled Vein.
Eurypterus Shales of the Shawangunk Mountains in Eastern New York.
White, David. A Remarkable Fossil Tree Trunk from the Middle Devonic of New York.
Berkey, C. P. Structural and Stratigraphic Features of the Basal Gneisses of the Highlands.


118 Clarke, J. M. & Luther, D. D. Geologic Maps and Descriptions of the Portage and Nunda Quadrangles including a map of Letchworth Park. 50p. 16pl. 4 maps. Jan. 1908. 35c.

126 Miller, W. J. Geology of the Remsen Quadrangle. 54p. il. 11pl. map. Jan. 1909. 25c.


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Itineraries of 32 trips covering nearly the entire series of Paleozoic rocks, prepared specially for the use of teachers and students desiring to acquaint themselves more intimately with the classic rocks of this State.


Guides


— Map of the State of New York Showing the Location of Quarries of Stone Used for Building and Road Metal. 1897. Out of print.

— Map of the State of New York Showing the Distribution of the Rocks Most Useful for Road Metal. 1897. Out of print.

— Geologic Map of New York. 1901. Scale 5 miles to 1 inch. In atlas form $2.

Separate sheets of this map are available at 50c each, as follows:

Ontario West: Finger Lakes Delaware
Niagara Long Island Adirondack
South Western St Lawrence Hudson Mohawk
Ontario East Central Lower Hudson
Ontario East Delaware

(Note) The Ontario West and Ontario East are not colored as they have no surface geology.

The lower Hudson sheet, geologically colored, comprises Rockland, Orange, Dutchess, Putnam, Westchester, New York, Richmond, Kings, Queens and Nassau counties, and parts of Sullivan, Ulster and Suffolk counties; also northeastern New Jersey and part of western Connecticut.
Map of New York Showing the Surface Configuration and Water Sheds 1901. Scale 12 miles to 1 inch. Out of print.

Map of the State of New York Showing the Location of Its Economic Deposits. 1904. Scale 12 miles to 1 inch. 15c.

Geologic maps on the United States Geological Survey topographic base. Scale 1 in. = 1 m. Those marked with an asterisk have also been published separately.

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New York State Museum Bulletin
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No. 261 ALBANY, N. Y. JUNE 1925

New York State Museum
JOHN M. CLARKE, Director

GEOLOGY OF THE AUSABLE QUADRANGLE

BY
JAMES F. KEMP AND HAROLD L. ALLING

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GEOLOGY OF THE AUSABLE QUADRANGLE

BY

JAMES F. KEMP AND HAROLD L. ALLING

INTRODUCTION

The Ausable quadrangle lies to the east and northeast of the higher parts of the Adirondacks. Its mountains are marked by a decided decrease in altitude from the peaks of all three of the quadrangles which touch it on the west, southwest and south. Its most pronounced topographic feature is a northeast ridge which crosses the quadrangle diagonally. To the northwest of the ridge is a broad open valley, buried in sandy deposits of the later Pleistocene. To the southeast the character is much the same. The culminating point in elevation is Saddleback mountain at 3623 feet. There are four lower peaks which exceed 3000 feet; two others above 2900 feet, and then all the other summits are not much above 2000 feet or are decidedly less.

The low points are found at three places where the lines of drainage cross the eastern border. The Ausable river takes the waters of somewhat more than the northwestern half of the area and passes on to Lake Champlain at 430 feet. The north branch of the Boquet river and its tributaries leave the southeastern edge at the same altitude; but the lowest point of all, 400 feet, is in the extreme southeastern corner, where a small brook enters the main Boquet just at the edge of the map—the river itself being a few feet within the Elizabethtown sheet. There is thus an extreme range of about 3200 feet.

There are two lakes of moderate size, Augur lake on the eastern border, but with its largest portion in the Willsboro quadrangle, next east, and Fern lake in the northwestern corner. There are a number of peculiar ponds in the central portion, which furnish subjects of interest for the chapter on Pleistocene geology.
Considering the structural features in general, while there is still the pronounced northeast and southwest ridge, so characteristic of the eastern Adirondacks, we no longer find the marked northwest breaks, giving rise to the "trellised" drainage of the Mount Marcy and Elizabethtown quadrangles and described in the bulletins on these areas. The Ausable area presents much greater irregularity and lack of system in its relief.

Although the mountains do not attain great altitudes, they are extremely rough and rugged. Even before the forest fires of 1913, they were rendered difficult of access by the lumbering operations and the thick second growth, but since the fires they are much worse.

The quadrangle is on the whole sparsely settled. The principal town is Ausable Forks, which in the prosperous times of the iron mines at Palmer Hill and the bloomeries or forges fed by them, possessed even a modest rolling mill. The large pulp mill a mile to the west has maintained avenues of employment since the iron industry waned. Clintonville, 5 miles east, down the Ausable river from the "Forks" had its maximum population when the Arnold mines to the north and other smaller ones nearer the village were active. Jay about 6 miles up the East Branch from the "Forks" is an attractive village with a goodly number of summer visitors. Lewis on the southeast is the center of a farming region. Aside from these villages the area is one of scattered farms or uninhabited mountains.¹

GEOLOGICAL OUTLINE

With the exception of some narrow basaltic dikes, which were probably injected in the post-Ordovician time of the Paleozoic, the geological formations are either Precambrian crystalline rocks at the base of the geological column; or else are sands and gravels of the Pleistocene, at its summit. A small area of Potsdam sandstone lies about three-quarters of a mile north of Ferrona, at a point 5 miles west of the northeast corner of the quadrangle just north of the boundary line, and may indeed actually touch or extend a few feet south into it; but this is the only apparent possibility of Paleozoic strata, even making due allowance for what may lie beneath the heavy mantle of sand and gravel. When arranged in a stratigraphic table, the formations group themselves as follows:

¹ For important assistance in the field work performed in the preparation of this bulletin, acknowledgment is due and is gladly made to Alfred T. Child, Morrison B. Yung, Fred J. Pope, G. H. Chadwick and D. H. Newland. Much detailed observation, originally made under the United States Geological Survey, has been generously placed at the service of the New York State Survey.
In the use of several of the above larger terms, the writers have perhaps gone a step farther than has been usual in Adirondack geology, in suggesting correlations with one or two formations whose typical development is in the Lake Superior region. While correlations, essentially made on the basis of the kinds of rocks, are to be taken with some reserve; yet both in this respect and in their apparent place in time, the parallels are sufficiently close to justify the general grouping.

The strong probability that the diabase dikes of this region correspond to the great outbreak of basaltic rocks of the Keweenawan of Lake Superior, was first suggested by H. P. Cushing in 1901. We certainly know that these dikes are older than the Potsdam and that they escaped the crushing or more intense metamorphism to which the next older rocks have been subjected. Stratigraphy is simplified if we avail ourselves of a name already current.

Algoman as a stratigraphic name was first applied by A. C. Lawson in the Rainy lake region of northern Minnesota and western Ontario. Under it Doctor Lawson grouped a series of intrusive rocks which were later than the Huronian. The use of Algoman in Adirondack geology has been the subject of discussion in the

<table>
<thead>
<tr>
<th>Period</th>
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<td>Recent: Alluvial sands and gravels, Post-glacial deltas and lake beds, Morainal deposits</td>
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<tr>
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<td>Pleistocene: Post-glacial deltas and lake beds, Morainal deposits</td>
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<tr>
<td>Paleozoic</td>
<td>Post-Ordovician: Camptonite dikes</td>
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<td>Keweenawan: Diabase dikes</td>
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<td>Precambrian</td>
<td>Algoman: Basic gabbros, Syenite series embracing soda-granite and quartz-nordmarkite, Anorthosites</td>
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<td></td>
<td>Laurentian: Metadorite, Potash granite, Metagabbro</td>
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<td></td>
<td>Grenville: Limestones, quartzites, parschists and paragneisses.</td>
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<td>Keewatin?: Greenstones</td>
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past between each of us and Professor Cushing, but so far as we know, the only previous uses of it in print are the ones cited below. We are placing under Algoman the rocks hitherto called basic gabbros, the syenite series and the anorthosites. The first named are largely norites in mineralogy, but in all cases show the rich formation of a secondary mineral, garnet, which may date back to a time closely following the beginning of crystallization in the magma. The second series, the so-called syenites, we know to be notably high in soda. In the Ausable quadrangle they include both soda-granite and a rock which, while too low in silica to be a true granite, yet has a notable amount of quartz. It corresponds very well to the rocks called nordmarkite by W. C. Brøgger which are extensive in the Christiania region, Norway. They are also closely analogous to the mangerites of Kolderup in the Bergen district of Norway, where they are associated with anorthosites precisely as in the Adirondacks.

In the interest of a more solidly grounded correlation, we are unfortunate in having no strata in the Adirondacks which can be made a parallel with the Huronian of the region of Lakes Huron and Superior. Apparently in this period the New York area was land. We do know, however, that there are intrusive granites which penetrate the Grenville strata and include fragments of them torn off from parent masses. These we class as Laurentian. They are notably rich in potash feldspar as contrasted with the abundance of soda-feldspars, pyroxenes and hornblendes in the syenite series of the Algoman. There are also amphibolites, believed to represent ancient diorites and gabbros (metadiorite and metagabbro) which we also place in the Laurentian.

The Grenville strata are similar to the exposures already described from other localities in the eastern Adirondacks where they have been studied by both of us. One of us has formulated a stratigraphical classification which treats these ancient and greatly

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5 W. C. Brøgger, Zeitschr. f. Kryst. 16:54. 1890. Nordmarkites are rocks of granitoid texture, consisting of orthoclase, oligoclase, micro-perthite and somewhat subordinate biotite, pyroxene, hornblende and aegirite. They are quite variable in composition and are transition members from syenites, rich in soda, to granites, also rich in soda.


metamorphosed strata, in the same way as one would those of Paleozoic or later date. The classification has proved usefully applicable in many separated areas.

The use of the term "Keewatin" for the oldest rocks in the regions north of the Great Lakes, and especially for greenstones and amphibolites, has led us to employ it tentatively for the ancient amphibolites, which are the oldest rocks in the region discussed. These amphibolites may be in instances ancient gabbros, in which case they could be properly named metagabbro; possibly they were once diabases, or basaltic effusives or even pyroclastics. The non-committal name "greenstone" might be applied to them. At all events, as we now see them, hornblende is the most prominent constituent. We can not positively state that they are of Keewatin age. Some might conceivably belong to the Grenville, but we find Keewatin a very convenient term.

NOMENCLATURE AND CORRELATION

We have applied the nomenclature of the Canadian geologists to the Adirondack rocks with the hope that certain relationships and possible correlation would be revealed. While we believe that the use of the terms, "Keewatin," "Laurentian," "Huronian," and "Algoman" have proved very suggestive and useful, we are, however, aware that at this writing (November 1920) there is a strong tendency on the part of the younger members of the Canadian survey to return to the former practice of employing local nomenclature instead of the more general terms. M. E. Wilson has given a clear statement as to why inter-subprovincial nomenclature is objectionable and misleading, as it often is. There are advantages as well as objections to a general nomenclature. Opinions differ according to personal experience whether such tentative correlations are a help or a hindrance to satisfactory conclusions.

In the Adirondacks Precambrian sediments other than the Grenville are apparently lacking and thus we have been compelled to emphasize the succession of batholithic intrusions and their relations to each other as a basis for correlation. In 1916 the accounts of the majority of the Precambrian areas showed that there are at least two periods of granitic intrusions prior to the Keweenawan. Upon this basis Lawson proposed the term "Algoman" and sug-

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8 Wilson, M. E., Timiskaming County, Quebec, Canada. Department Mines, Memo. 103, 1918, p. 65-75.
gested correlations that advanced our knowledge of the Precambrian. However, "geological investigation throughout the world has shown that batholithic intrusions are an accompaniment of mountain building movement."\textsuperscript{10} It follows that deep-seated igneous rocks occupy cores of mountain ranges and so it would be surprising if such rocks should have a great areal extent. If three intrusives of similar character are present, it would be almost impossible to distinguish them.

Thus the Canadian workers have questioned the soundness of Lawson's hypothesis "that throughout the region extending from the Adirondacks to northwestern Ontario there were in Precambrian time 'two and only two periods in which great granitic batholiths were developed in the earth's crust.'" M. E. Wilson and others are now referring to pre-Cobalt and post-Cobalt intrusions and even omit the term "Laurentian." These workers are of the opinion that it is unwise to attempt correlations in the light of our present knowledge and in the darkness of our present ignorance.

We do not fully concede this view. We are convinced that the use of the names which M. E. Wilson and his associates are criticizing has been and is of value to Adirondack workers and while we are aware that future work may disprove some of our conclusions and alter our nomenclature we believe that this bulletin states the present status of the Adirondack Precambrian.

If we should delay positive statements until we were fully satisfied that the Lake Superior and Canadian Precambrian had been completely deciphered we might as well postpone indefinitely any attempt at the use of the same names, and would in the meantime lose the great convenience of a series of terms which are applied over a wide area to similar rocks, following one another so far as we can determine in a similar sequence.

Advancing and illuminating investigations by Charles P. Berkey in southeastern New York, and the notable work of the Canadian geologists north of the Great Lakes have led to the preparation of the accompanying table of suggested parallels, since the Adirondack region lies between the two, and is separated from each by broad areas of Paleozoic strata. Professor Berkey has been kind enough to discuss freely his results with us. They relate especially to the West Point quadrangle, (New York State Museum Bulletin 225–26, 1919).

\textsuperscript{10} Wilson, M. E., Canada, Department of Mines, Mon. 103, 1918, p. 68.
## Precambrian Correlation

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<td>Nipissing</td>
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<td>Sudbury Norite</td>
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<td>(Whitewater series)</td>
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<td>Ramsay Lake series</td>
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<td>Algoman</td>
<td>Lorrain, Norian</td>
<td>Norite</td>
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<td>Quartz Nordmarkite</td>
<td>Yonkers Granite</td>
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<td>Anorthosite</td>
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<td>Upper Huronian</td>
<td>Whitewater series</td>
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<td>Reservoir Granite</td>
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<td>Fabre series</td>
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<td>Mattigami?</td>
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<td>Hastings series</td>
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<td>Laurentian</td>
<td>Ottawa Gneiss</td>
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<td>Grenvillian</td>
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<td>Keewatin</td>
<td>Keewatin</td>
<td>Greenstones</td>
<td>Fordham?</td>
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### ORTHO-AMPHIBOLITES\(^{11}\) OR GREENSTONES OF KEEWATIN (?) AGE

Greenish brown inclusions in the major eruptives have been noted and described from various localities in the Adirondacks. In general they are equigranular rocks composed of hornblende and plagioclase as essential minerals, with augite, garnet, magnetite and biotite as common accessories. Occasionally apatite, pyrite and zircon are found in addition. With the commonly accepted view that blocks of calcareous shales of the Grenville series could assume the chemical and mineralogical character possessed by these rocks when caught up by the great intrusives, and subjected to magmatic "cooking," they have been regarded and mapped as Grenville xenoliths.\(^{12}\) On the other hand, an igneous origin has been assigned to

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\(^{11}\) By ortho-amphibolite we mean a metamorphic rock, now largely or predominantly hornblende, derived from an igneous original, of whose exact nature we are not certain. Gabbros, diabases, basalts, pyroxenites and peridotites would be the most probable sources. Amphibolites of sedimentary originals we would call para-amphibolites or paramphibolites.

\(^{12}\) Adams, F. D., Jour. Geol. 16: 623-24.
some of them. The latter interpretation has been the result of detailed work in the western Adirondacks. Smyth\textsuperscript{13}, Cushing\textsuperscript{14}, and later, Martin\textsuperscript{15} have gone on record as believing that some of these ancient rocks represent igneous activity antedating the Laurentian and Algoman eruptives.

Still a third interpretation is that some of them are contact rocks produced by the action of the granites upon limestones of the Grenville series. It is therefore possible that the amphibolites of the Ausable quadrangle have been derived from three distinct sources.

One of us in 1910 described a peculiar gabbro near Elizabethtown,\textsuperscript{16} referring to it as the "Woolen Mill" type. It has the general mineralogy of gabbros, but lacks all the normal textural and structural characters of the Algoman representative. It also contains quartz in addition to the minerals of the Algoman gabbros (then called basic gabbros); and its garnet was not the granular garnet in reaction rims, so abundant in these gabbros. It had occasionally scattered in it large blue labradorites, such as are found in the anorthosites. Its border as against the neighboring anorthosite was mapped in detail and given in figure 7 on page 42 of the bulletin cited. Each rock in instances appears to be intrusive in the other. The Woolen Mill type was markedly gneissoid and was such a puzzle that two analyses were made and recast, showing, however, such variability as to add to the confusion from the old point of view that the rock was a crushed and metamorphosed "basic gabbro." We recognize now that it undoubtedly is an ancient orthoamphibolite, older than the anorthosites, penetrated by them and to a greater or less degree, in one place and another, affected and "soaked" with contributions from the anorthosite, of which the large blue labradorite crystals are the most easily detected.

The assignment of some of the ortho-amphibolites to an ancient, possibly Keewatin period, and probably to some original igneous rock, gabbro, or basalt, simplifies many of the difficulties. Whether, however, they are of Grenville or Keewatin age can not be decided in a locality where no certain exposures of either are associated. We therefore note the similarities with the cases studied in the western Adirondacks and remark Keewatin possibility. In the Mount Marcy bulletin, in the discussion of the Woolen Mill type, a Grenville age is suggested.

\textsuperscript{15} Martin, J. G., N. Y. State Mus. Bul. 185, 1916, p. 86-93.
After studying the green amphibolitic inclusions in the Laurentian granite of the Canton quadrangle and reaching a conclusion in accord with Cushing and Martin, one of us pursued geologic work in the southeastern Adirondacks,17 with the expectation of finding ancient igneous rocks of gabbroic character. Such rocks were found and described in the bulletin above referred to. In the Whitehall quadrangle a gabbroic laccolithic sheet was found that was demonstrated to be of post-Laurentian-granite age, but earlier than the Algoman. In the Paradox lake quadrangle ortho-amphibolites were encountered that were regarded as even older than those found in the Whitehall district. Impressed with the presence and abundance of the ancient gabbroic masses, we looked for similar ones in the northeastern Adirondacks. Instead of finding laccolithic bodies associated with the Laurentian granite, long, narrow dike-like masses were found surrounded by anorthosite. These were described in 1919 as "peculiar gabbroic dikes."18 One of these so-called dikes, occurring in the Ausable sheet was revisited by us, and found to be cut by tongues of anorthosite. The "Woolen Mill" occurrence was at once recalled. These so-called dikes were not intrusive into the anorthosite but were xenoliths within it, and consequently of an earlier age. Similar ones have been found occurring throughout the quadrangle. After quantitative petrographic study these were interpreted as ancient lava flows or pyroclastic deposits. The most satisfactory petrologic name that can be attached to them is ortho-amphibolite or greenstone.

In respect to the age of the greenstones there is some uncertainty. While all that we have seen are demonstrably older than any of the Algoman intrusives, their relation to the Laurentian granite is not so clear. The Whitehall laccolithic sheet spread itself out on top of a thick bed of Grenville quartzite which had previously been saturated by magmatic matters from the underlying Laurentian granite. The slides of this mass differ somewhat from those taken from inclusions found in the Ausable quadrangle. Although this is not conclusive evidence that they are of two different ages yet it is our belief that the Ausable rocks are analogous to the western amphibolites. If they are, as above suggested, ancient lava flows or pyroclastics, the question arises: What would be the most reasonable age to assign to them? The correlation tables of Canadian and Lake Superior Precambrian areas at once suggest a Keewatin age. Con-

sequently we are tentatively regarding them older than the Grenville. Even though this is not as yet proved, we are confident that they represent a very old, if not the oldest, igneous rock in the Adirondacks. In this belief we are in accord with Doctor Cushing. Professor Miller in the Lake Placid bulletin has suggested that similar rocks in that area may be older than the anorthosite, yet he is a little cautious in stating that the relationships are as we have above suggested. In a later paper\textsuperscript{19} he voices the opinion that they are clearly older than the Algoman granites of the Lyon mountain region, but possibly younger than the Grenville. The ortho-amphibolite masses play an important rôle in Miller's theory of the origin of the magnetite deposits on Lyon mountain, but the discussion of this matter is deferred until a later page.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Sketch of scarp face of Pokamoonshine mountain, looking east, showing inclusion of ortho-amphibolite in Algoman granite and the faulted diabase dike.}
\end{figure}

The conception that they are lava flows may perhaps help to explain their peculiar shapes. Usually they are slabs from four to twenty feet thick and many times as long. This habit caused one of us formerly to consider them as dikes. Their great length often prevents their complete exposure in a single outcrop.

The most remarkable and instructive example of these ortho-amphibolite xenoliths is in the granite on the faultline escarpment of Pokamoonshine mountain. It is about 15 feet in thickness and is exposed for nearly 300 feet. The foliation of the granite has been

\textsuperscript{19} Miller, W. J., Econ. Geol., v. 14, 1919, p. 510–11.
affected by its presence; the lines of flowage being well shown curving around one end of the mass. This can be seen from the roadway. Figure 1 is a sketch of the occurrence. Above the ortho-amphibolite xenolith in the cliff is a basaltic dike (diabase) which has suffered repeated displacement through minor faulting. Plate 1 is a photograph of this.

Petrographically the Keewatin (?) greenstones are composed of green hornblende and plagioclase. The latter varies from an acid andesine to labradorite. Less commonly augite is found in addition. When quartz is seen in any appreciable amount there is reason to believe that it is secondary. Garnet is very often present in equigranular masses uniformly distributed throughout the rock. Mag-
netite, pyrite, apatite and zircon complete the list. A diagram showing the relative abundance of the minerals is given in figure 2 which is based upon quantitative microscopic analyses.

While these rocks are regarded as igneous there are similar looking rocks throughout the area that may have had a different origin. The amphibolites, as above noted, can conceivably be derived from igneous or sedimentary originals. It is but a reasonable supposition that those due to sedimentary processes are of Grenville age, even though no further information is at hand. The difficulty is in distinguishing these two similar rocks from each other. One of us has proposed criteria by means of which this distinction can be made. These consist of the following:

<table>
<thead>
<tr>
<th>Sedimentary Origin</th>
<th>Igneous Origin</th>
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<tr>
<td>Original Quartz</td>
<td>High Pyroxene Content</td>
</tr>
<tr>
<td>Motley Collection of Feldspars</td>
<td>Evenly &quot;split&quot; Feldspars</td>
</tr>
</tbody>
</table>

A diagram showing the composition of a paramphibolite inclusion, supposedly of Grenville age, is given in the same figure (figure 2) for comparison with those of Keewatin (?) ortho-amphibolites.

THE GRENVILLE SYSTEM

The Grenville strata appear in some twenty-six separate areas of varying size but even in the smaller instances of approximately a half a mile as minimum diameter. Of these perhaps two-thirds might be considered large xenoliths, since they are fragments caught up in the later intrusives and in almost all cases in anorthosite. Since the anorthosite is the oldest of the Algoman igneous rocks and is very extensive in the quadrangle, perhaps we ought not to be surprised that the Grenville strata were fairly overwhelmed by it before the entrance of the syenitic intrusives which followed. We note several Grenville areas on the contacts of the anorthosites and the syenitic, or as we have called the latter the nordmarkitic, series, but only one or two small areas exclusively in the latter. In

22 The phrase “evenly ‘split’ feldspars” has reference to the freezing of a feldspar magma. If the feldspathic composition were on the potash side of the eutectic line in the thermo-equilibrium diagram of the feldspar system, the resulting crystals would be dominantly of the orthoclase type of feldspar, while if it were on the other side, plagioclase (plus a little potash feldspar) would result. But if the position of the molten feldspar were on or near the eutectic line, the solid minerals would be dividing on freezing into orthoclase (or microcline) carrying a little soda feldspar in solid solution, and plagioclase.
Plate 1

Pokamoonshee mountain escarpment face of soda granite holding inclusion of Keewatin (?) orthoamphibolite (Oa) and cut by a faulted diabase dike (Dd) of Keweenawan (?) age. The outlines of the inclusion and of the dike have been strengthened. Photograph by H. L. Alling in 1919.
the large way these relationships corroborate the older age of the anorthosites as against the syenitic series.

Not all the Grenville areas contain crystalline limestones, but at least nineteen separate exposures of this easily determined rock have been recorded. Even when we include the xenoliths in our field of view, the Grenville exposures have a marked distribution along the northeast and southwest diagonal of the quadrangle, and are notably lacking in the northwestern and southeastern portions. This same alinement continues to the southwest, across the Lake Placid and for several miles into the Mount Marcy quadrangle.

We have been led to look into the distribution of the Grenville areas in several other localities of the northeastern Adirondacks in so far as maps and combined field experience have furnished the data and are somewhat strongly impressed with this character, despite the disturbances produced by the Laurentian and Algoman intrusives. There is some evidence still surviving of structural lines of a northeast and southwest direction, probably due to orogenic upheaval preceding the igneous outbreaks. That the Gren-
ville strata were metamorphosed before the entrance of the Algoman anorthosite is quite soundly established and is more fully discussed in the survey of the Mount Marcy quadrangle. The excessive flowage phenomena of the limestones, which led Ebenezer Emmons in the early state survey work to consider them igneous, may date back to these disturbances. Figure 3 is drawn from a photograph of two specimens of contorted thin layers of silicates, which had been dissolved free from the limestone, at the mouth of a spring in the exposure 4 miles nearly due north of Lewis village. The limestone is included in anorthosite. In order to explain the double folding and compression of the thin layers of normally brittle silicates we must assume viscous flowage, analogous to dough, and at the time under extreme pressure — with no appreciable possibility of cracking and offsetting.

Grenville Stratigraphy

It is a natural desire on the part of Adirondack geologists to establish the stratigraphic succession of the Grenville series. Stratigraphic sections at Port Henry plotted by one of us showed among other relationships that the serpentine limestone (ophicalcite) is stratigraphically above white limestone which seems to be the reverse of the relations shown by the Trout pond section in the Ausable quadrangle. It is quite possible, however, that at Port Henry the section there exposed represents a different portion of the Grenville series. Dr I. H. Ogilvie was also one of the earlier workers to give a positive suggestion relative to the stratigraphy of the Grenville rocks within a quadrangle. She pointed out many relationships that have been verified by later work and some which have been modified. Miller in 1914 described a large number of different types of Grenville rocks for he says: "if the broader structural and stratigraphic relations of the Grenville series are ever to be worked out, it is necessary to have these rocks carefully described and mapped over a much larger area than that of a single quadrangle." He gives several cross sections of the North Creek sheet, but Miller's units are far too large for satisfactory correlation with the sections as revealed by our study of the Ausable

quadrangle. In 1917 and 1918 one of us was able to establish the succession of 1000 feet of the Grenville series in the southeastern Adirondacks. This geologic column is given in column 2 of table 3. Three stratigraphic sections within the Ausable quadrangle have been deciphered and are reproduced here in columns 3, 4 and 5. One is the area to the southeast of Trout pond, which in part constitutes the Smith graphite property and which has received rather full treatment elsewhere. The second section is at the western end of the gulf in the north central portion of the quadrangle. The third locality is on the southwestern slopes of Jay mountain in Cherry glen.

**Trout pond section.** The Grenville rocks here form a distorted northward pitching anticline, the basal portions and limbs of which have been assimilated and dissolved away by the quartz nordmarkite and anorthosite intrusives. The quartzose members have been soaked to a limited degree by the Laurentian granite.

The lowest bed here exposed is a par amphibolite estimated to be about 100 feet thick and correlated with the Dresden par amphibolite of the Hooper graphite property in the Whitehall quadrangle. The upper layers of the Dresden are much more siliceous. When first observed, this change in composition was credited to the presence of the Laurentian granite, but a thin section showed that the quartz grains are primary. A few needles of biotite and sillimanite suggest the next higher formation, the Hague gneiss, although good exposures are lacking. The type locality of the Hague is the town of Hague on Lake George where it occurs as a feldspathic quartzite containing garnet and sillimanite.\(^\text{27}\)

Above the Hague is a 50-foot (approximate thickness) bed of serpentinized limestone. The stratigraphic column established for the southeastern Adirondacks (column 2 in table 3) lacks any such formation. Consequently a local name has been necessary. The term Chesterfield limestone, from the township in which it occurs, has been applied to it. It is uncertain whether the Chesterfield represents the upper beds of the Hague or is introduced by a minor unconformity.

Next in order, above, is the graphitic quartz schist, which averages 10 feet in thickness. It is chiefly composed of interlocking grains of quartz with from 8 to 14 per cent of graphite. This stratum has been traced (not continuously to be sure) from the middle of the present quadrangle south to Saratoga Springs, a dis-

tance of 90 miles, and from Hague, on Lake George, west to Conklingville, a distance of 40 miles. An entirely satisfactory name has not been found for it but we are provisionally referring to it as the "Dixon" schist.²⁸

In the generalized column the Faxon limestone is inserted between the "Dixon" and the Swede pond quartzite. This limestone is erratic, appearing in the sections to the west of Lake George but usually being absent along the eastern margin of the Adirondacks and in the Ausable sheet or occurring as a very thin bed. Directly on top of the Dixon is a very thin layer of limestone which is probably the Faxon.

Above the graphite schist, occupying a position above the Faxon horizon, is a 50-foot bed of quartzite here listed as the lower Swede pond. The Trout pond limestone intervenes between the lower and upper Swede pond formations. It is not fully understood why the Trout pond seems to occupy a position near the base of the original Swede pond unit of the Dixon-Faxon properties near Graphite.

Overlying the upper Swede pond quartzite is the sillimanite schist named the Catamount.

Upon the Smith property we find the Bear pond schist, a felspathic quartz, graphite schist, surmounting the Catamount. Although it is a graphite bearing rock it is too low in that mineral to possess any commercial significance. This completes the section so far as yet revealed, although it is possible that further examination of the Grenville rocks farther south might bring to light additional formational units.

**Gulf section.** The detailed account of this locality given in the report on the graphite deposits renders a full description unnecessary. The Grenville rocks are strongly dipping to the east and penetrated by both the Whiteface anorthosite and quartz nordmarkite. The lowest Grenville member observed is the lower Swede pond quartzite, the basal portion of which contains large flakes of graphite in small amounts. The inference that we draw from this is that either this graphitic layer actually represents the "Dixon" or that the graphite has been derived by pegmatitic activity from that formation situated below. (See "Economic Geology" on a later page.) After making allowances for the tongues of Whiteface anorthosite the lower Swede pond formation is estimated to be about 50 feet thick.

Stratigraphically above this quartzite is the Trout pond limestone containing the usual dark silicates but no graphite. This is some 50 feet thick. This limestone is succeeded by a narrow bed of quartz-orthoclase schist which is interpreted as a transitional phase from the Trout pond to the upper Swede pond. Higher beds have not been identified. Excessive faulting in the district renders conclusions difficult. The Trout pond and the upper Swede pond seem to be repeated eastward by faulting.

**Cherry glen section.** This section on the western slopes of Jay mountain is significant in its bearing on the origin of the pegmatite-contact type of graphite. This matter will receive attention on a later page. Graphite has been developed by pegmatites in contact with the Trout pond limestone and the basal layers of the upper Swede pond quartzite. It seems very clear that the "Dixon" lies beneath the Trout pond and the lower Swede pond as the source of the graphite although it was not seen. About 30 feet of the Trout pond formation and 270 feet of the upper Swede pond quartzite are exposed. There is a gap in the section of 100 feet; then another paramphibolite outcrops. From the exposures of the latter we infer it to be 100 feet in thickness. There seems no doubt that it is the Beech mountain paramphibolite of the Faxon property. Higher formations were not looked for.

**Hale brook section.** A section of the Grenville rocks in the Hale brook park was mapped in detail by one of us in 1899. The accompanying figure shows the section as interpreted in the light of recent work. The strike of the beds is nearly north and south and they dip at a low angle to the west. The lowest bed exposed is a paramphibolite which is calculated to be about 52 feet thick, and is tentatively correlated with the Dresden. Upon this formation is a stratum of perhaps slightly greater thickness which was called a white or whitish gneiss. This may very well be the Hague gneiss. Near the top of this unit it is well banded. This is succeeded by a comparatively thin bed of rusty graphite schist. This is correlated with the "Dixon." On top of the graphitic member is lime-
stone. The limestone is exposed along the outcrop, perpendicular to the strike, for 800 to 900 feet, as determined by pacing, giving the impression that a very thick bed is exposed. There is, however, reason to believe that the dip is very low and consequently the bed may not exceed 50 feet in thickness. Assuming that the other beds have been correlated properly, we must assign this bed to the Faxon formation as shown in column 2 of the table. The Hale brook section is located to the southwest of the Trout pond section, where, as will be recalled, the rocks are folded into an anticline. It is quite possible that the beds in the Hale brook park form the western limb of the same anticline. Abundant evidence from the field has demonstrated that the limestones are often molded and squeezed like so much putty especially when subjected to severe isoclinal folding. Under such conditions they are often squeezed out and fail to appear along the crest while they do appear along the limbs of the fold. The Trout pond section shows only a trace of the Faxon in one of the pits dug to reveal the graphite schist. The two limestones, the Chesterfield and the Trout pond, are better exposed along the eastern limb of the Trout pond anticline and only appear as thin ribbons along the crest or axis of the fold. Thus making allowances for the squeezing out of the Faxon limestone on the Smith property we can understand its appearance along the western limb of the anticline as revealed in the Hale brook section.

The significance of the progress so far made to decipher the stratigraphy of the Grenville series lies in the fact that when small formational units are chosen it is possible to correlate many sections over considerable distances. The erratic character of the limestones, and their greater abundance to the west would lead us to infer that during the Grenville time interval represented by these sections, deeper water conditions lay to the west and conversely that shallow water and the shore line were to the east.²⁹

The employment of these small units brings to light the fact that the Grenville series, in many places, is complexly folded, frequently isoclinally. The evidence seriously questions the repeated statement that the Grenville series was many miles thick. The sections so far studied represent, however, only a small portion of the entire series.

Folded Grenville limestone resting upon undisturbed Grenville quartz schist. Both in contact with quartz nordmarkite. Western end of the faultline valley known as the Gulf. Photograph by H. L. Alling in 1916.
### Table 3

Grenville Stratigraphy Correlation

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<td>2 Alling 1917 Southeast Adirondacks</td>
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<td>5 Alling 1919 Cherry Glen Ausable Quad.</td>
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It is quite obvious that correlations in the Precambrian are much more difficult than in similar studies of nonmetamorphosed Paleozoic strata. In the Grenville series fossils are totally lacking; each orogenic disturbance has superimposed its modifications upon the normal variations that obtained due to conditions of deposition. The methods that are now available for the Precambrian stratigrapher are practically limited to two, stratigraphic succession and lithologic similarity. In regard to the last, it is of interest to note R. D. Irving's opinion in 1886.footnote

An exceedingly difficult handicap that Nature has imposed upon the Precambrian stratigrapher is the fact that the Grenville rocks, especially those which exist in small patches, floating upon the solidified magmas, are rarely free from contributions from such underlying rocks. The saturations, the soakings, the lit-par-lit injections, and magmatic cooking result in mineralogical combinations that in many places make deciphering impossible. It is not sufficient to describe a sediment with the hope that future work will establish a pigeon hole into which such a formation will fit. The history of the rock must be secured; the protoclastic and the cataclastic structures must be distinguished and classified. The nature of the original must be inferred and from that the conditions under which it was deposited. This work must be, by the nature of the material at hand, largely petrographic; not descriptive but interpretive. Interpretation requires a petrographic knowledge of non-metamorphic sediments—a field of geology hardly entered. Of the Grenville system in the eastern Adirondacks we do not yet know the top or the bottom, its thickness, or conditions under which it was deposited. Our study is but the very beginning.

An exceedingly instructive example of the problems that the Precambrian stratigrapher meets is the Hague gneiss. One of us has found it in many localities separated by many miles. At the type locality it is a feldspathic quartzite, with a low content of sillimanite and garnet. So distinctive are the last two minerals that it has been referred to as “the garnet-sillimanite gneiss.” At Hague and at Graphite the basal layers are soaked by the magmatic juices of the Laurentian granite. The petrographic interpretation of the above is that the original was an arkose with sufficient argillaceous matters to form the sillimanite upon metamorphism. While the garnet has never been separated and analyzed, one would naturally interpret it as indicating calcareous or magnesian matter in the original sediment. It may be in part due to magmatic contributions and cooking. At the Hooper mine in the Whitehall district the rock is quite similar but lacks the garnet, perhaps, to a large degree, because the Laurentian did not come in direct contact with it. At the Flake Graphite Company’s mine (Saratoga sheet) the Hague is exceedingly micaceous and nonresistant, rarely outcropping. At the Rowland mine (North Creek sheet) it is a quartzite, containing but little feldspar and no sillimanite and garnet. In the Ausable sheet it is largely a feldspar schist, composed of soda microcline, microperthite and some minor amounts of acid plagioclase and quartz. Here it
should be regarded as a meta-arkose or arkosite. Although it varies in details it preserves its general character, thickness and stratigraphic position throughout the eastern Adirondacks.

**Petrography of the Grenville**

**Crystalline limestones.** The limestones are of the white crystalline variety so characteristic of the Grenville exposures. Although generally coarse grained, crushing may locally produce fine-grained varieties. The limestones commonly contain flakes of graphite, and irregular individuals or streaks of silicates. The latter are most frequently diopside, but in places where contact metamorphism has been developed under the influence of the intrusives, reddish-brown garnet, which becomes salmon pink in thin sections, may also appear along with wollastonite, called “tabular spar” in the older books. The town of Lewis has been cited as one of the localities of tabular spar ever since the Natural History Survey of New York was completed in 1842.

Quartz appears frequently in the limestones. When in small scattered grains, it may be due to sand in the original sediment; when in larger streaks it is pegmatitic in its nature. With regard to the widespread streaks of silicates, the observer is sometimes in doubt, whether they are recrystallized shaly layers in the original sediment, or pegmatitic introductions from the never very remote intrusive rocks. Of metallic minerals both pyrrhotite and pyrite may be found.

From the small crescentic area of limestone a mile and a quarter north of “Cross” in the eastern central part of the quadrangle, the contact, garnet-diopside rock has been collected in characteristic development. Two miles southwest of Lewis, a deeply weathered boulder of unusually good wollastonite and garnet was found, but

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81 In Dr Lewis C. Beck’s valuable report on the Mineralogy of New York, 1842, p. 270-71, we find recorded:

“In the town of Lewis, about 10 miles south of Keeseville, tabular spar is found in abundance, with similar associates as in the last named locality (i.e. Willsborough). The garnet exhibits various colors; it is massive and in grains, forming the variety called *colophonite*. The tabular spar is very friable, and has a white or yellowish white color.

About a mile and a half north of Lewis Corners, there is another locality. The mineral here is snow white and closely resembles that from Easton in Pennsylvania. It is associated with garnet and quartz, the latter of which gives a sharpness to the masses of tabular spar, which it does not usually possess.”

These are undoubtedly cases of the contact metamorphism of Grenville limestone by later intrusives.
the parent ledge was never located. In the narrow limestone area which comes north into the central part of the sheet from Elizabeth-town on the south, the commoner characteristic minerals were noted.

Serpentinized limestone, called the Chesterfield stratum in the detailed description of the Trout pond section above, has only been observed in this one locality in the quadrangle, although this variety of rock is common in a number of Grenville exposures farther south. Thin sections prove that the serpentine is derived from altered diopside as in the other areas.

Quartzites. When the siliceous members of the Grenville series become sufficiently pure to be principally composed of quartz they are referred to as quartzites. They constitute an important portion of the Grenville of the Ausable quadrangle. Their relative resistance to weathering causes them to form ridges, cliffs and ledges. Under the microscope quartz is the prominent mineral. It occurs as interlocking grains having the appearance of vein quartz, frequently showing shadowy or wavy extinction and being cloudy with gas bubbles. All of the original clastic texture has been destroyed by thorough recrystallization under static and dynamic metamorphism. There is almost always some evidence that a part of the quartz has been introduced. It is impossible to determine how much came in during the original cementation process and how much is due to deep-seated metamorphic changes. Feldspar rarely fails in the Grenville quartzites. It sometimes constitutes 60 to 80 per cent of the rock. As it is practically impossible to ascertain the composition of a hand specimen without microscopic aid, the feldspathic quartzites, and meta-arkoses (arkosites) are usually referred to as quartzites. The garnet-sillimanite paragneiss of Hague (the Hague gneiss) is really a feldspathic quartzite with a relatively low sillimanite and garnet content. The feldspar is generally potassic; usually soda microcline, but soda orthoclase is not uncommon. Sericite usually accompanies this form of feldspar. These quartzites with potassic feldspar are considered to be recrystallized argillaceous sandstones. Not all should be interpreted in this manner, however, for certain phases of the Swede pond quartzite have been found that were composed of nearly pure quartz but they have been feldsparized by subjection to the highly fluid solu-

tions of the Laurentian granite. Continued steeping in the vapors of this ancient intrusive has subsequently sericitized the feldspars. The Algoman eruptives have acted upon the quartzites in this way but to a lesser degree.

Plagioclase is frequently found in the quartzite and is usually accompanied by pyroxene or hornblende. These minerals doubtless appear in what were the original calcareous sandstones of the series. Sometimes the lime content was sufficiently high so that wernerite, wollastonite and epidote were developed by magmatic "cooking." The more impure varieties of the quartzite were more readily foliated into paraschists and paragneisses. The lowest bed of the upper Swede pond quartzite in the Gulf stratigraphic section is largely composed of soda orthoclase and is so highly foliated that under the hammer it splits into thin slabs with ease. Closely allied to the quartzites proper are the graphitic paraschists. So much does the graphite change the general appearance of a quartzite that they are readily distinguished from the more normal representatives. Detailed study shows, however, that one of the graphite members of the Grenville series (the so-called "Dixon" formation) is composed to a very large degree of quartz, while the graphite is present to the extent of 10 to 15 per cent by weight. In this extremely high grade potential ore, igneous influences are practically lacking. A lower grade of graphite schist occurs when contact effects of the Algoman granite have introduced a feldspathic content. The latter may constitute as high as 40 per cent of the rock. Mica, usually biotite, now bleached and altered to chlorite and secondary products, pyroxenes, and introduced pyrite are usually found accompanying the feldspar. The feldspar is more frequently potassic, ranging from soda orthoclase, soda microcline to microperthite. Plagioclase is less common and ranges around andesine in composition. One of the interesting characteristics of certain specimens of the Smith graphite schists, from near Trout pond, is the presence of introduced pyrite and zincblende. The former apparently is of magmatic origin and was precipitated by the aid of the graphite. This process has been recognized by Von Cotta, Jenney and Smyth. The last named points out the close genetic

33 Von Cotta, Treatise on Ore Deposits. English Translation, 1870, p. 46-47.
relationship between graphite and pyrite in such sediments. Apparent-ly this precipitation was continued for some time with minor interruptions or variations in intensity for the masses of pyrite are beautifully zonal in habit and very often occur as concentric shells coating flakes of graphite. The zincblende seems to have been introduced with some of the early pyrite but its rarity makes it difficult to fully ascertain its mode of development.

The Bear pond schist, the second graphitic schist recognized in the quadrangle and stratigraphically above the "Dixon" schist, is essentially a graphitic feldspar schist with a minor quartz content. The feldspars are chiefly microcline to perthitic in type. Biotite is more common in the Bear pond than in the "Dixon." The Bear pond schist is lower in graphitic content than the Dixon and averages 4.5 per cent by weight.

Sillimanite schists. These are in part the argillaceous members of the Grenville series, originally mud rocks, cemented into clay shales, possibly slates, and through profound metamorphism to sillimanite schists. They are feldspathic rocks with quartz, sillimanite, biotite and ilmenitic magnetite. The formational unit here called the Hague gneiss is decidedly quartzitic while the higher bed, named the Catamount, is feldspathic, both carrying sillimanite as the distinctive mineral. Sometimes garnet is present and when it occurs there is some evidence that igneous activity is responsible for its development. With an increasing lime content the argillaceous sediments have become hornblende rocks which pass by gradual degrees into the paramphibolites which are described below. Staur-olite, cyanite and rutile are occasionally noted in the slides. Biotite is a variable constituent, usually low in amount in the presence of sillimanite but becoming an important rock maker in the absence of the latter. The sillimanite schists are at times involved with igneous rocks, which, when in direct contact, appear to have produced iron-bearing garnet and occasionally spinel; but when affected only by magmatic vapors have brought about less revolutionary changes. The most complete changes result from lit-par-lit injection. The fact that the Grenville rocks are so rarely completely free from igneous influences renders simple explanations difficult. It is often impossible to determine what was the original rock, what proportion of the changes that have taken place are due to normal cementation, how much to conditions of deposition, how much to deep-seated static metamorphism and for how much the igneous rocks are responsible.
Biotitic schists. Although biotitic varieties of the Grenville have been noted in several places within the area, they have not been mentioned in the stratigraphic sections so far deciphered. Consequently the extent, thickness and position of these biotitic types are not accurately known. The biotitic schists are usually feldspathic rocks, relatively low in quartz and sillimanite. They must represent the more ferruginous clays of the ancient series.

Paramphibolites. These dark green to black rocks are composed of green hornblende and plagioclase as essential minerals. The iron content of the former is relatively low and the feldspar is usually andesine. Biotite is common but many slides fail to show it. Potassic feldspars are common and rarely fail. Augite is present in a few slides from exposures proven in the field to be sedimentary in origin. Primary quartz is most significant in establishing criteria for the recognition of their sedimentary origin.

These hornblende-plagioclase rocks of the Adirondacks offer a most difficult problem to the geologist. While it is a comparatively simple matter to describe them, it is much more difficult to trace their origin. We recognize that amphibolites may be the end-products of several distinct processes, as has already been pointed out. Satisfactory conclusions can be reached only when the data in each case are complete and the criteria reliable. The method followed by Adams and Barlow, that of tracing the "feather-amphibolites" step by step to magnesian limestone layers, can be used only to a limited extent. In the Ausable quadrangle we doubt if it is applicable, for we found in the Smith graphite area both the Chesterfield and the Trout pond limestones perfectly conformable with the Dresden amphibolite. There is no evidence that the amphibolite is more metamorphosed than the limestones. It is our belief that they are different today because they were different in original composition. The most reliable criterion for sedimentary amphibolites (paramphibolites) is their conformable contact with definite members of the Grenville series. A sill would probably not be so widespread or at a definite horizon; neither could several separate intrusive sheets probably enter at this one place in the series. The conformable character of the paramphibolites has been observed a sufficient number of times to draw the safe conclusion that considerable masses of amphibolite are sedimentary in origin. Upon this

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36 Adams, F. D. and Barlow, A. E., Canada, Dep't Mines, Geol. Surv. Mem. 6, p. 158-59.
basis we establish, as formational units, the Dresden and the Beech mountain paramphibolites.

In the Gulf section graphite has been developed by pegmatitic action upon limestone. The latter has been changed by the igneous rock into an amphibolite. It contains, beside the hornblende and plagioclase, clear white pyroxene and wernerite. The latter two minerals are contact minerals. Thus there are within the Ausable quadrangle amphibolites of contact origin. The igneous derived types have already been discussed.

Some of the ortho-amphibolites are interpreted as ancient lava flows or pyroclastics. Those which are lava flows are surely igneous in origin. The amphibolites of the second class mentioned present a problem of their own. If the relation of the Grenville to the Keewatin is one of replacing overlap as is believed by some Canadian geologists then it may be that some of the amphibolites that are conformable with and part of the Grenville are waterlaid volcanic dust and ash. They might have considerable variation in composition due to assorting by wind and water, and yet retain sufficient igneous character to render the establishment of criteria impossible. Thus it is possible that in the Adirondacks and in the Ausable sheet there are:

5 Amphibolites produced from limestone by contact action
4 Ortho-amphibolites of post-Laurentian-granite pre-Algoman age. (="Timiskamian")?
3 Ortho-amphibolites of post-Grenville-pre-Laurentian age
2 Paramphibolites of Grenville age
1 Ortho-amphibolites of Keewatin (?) age

It is no wonder that the amphibolites constitute a most difficult problem whose solution is by no means at hand.

Although our study of the Grenville leaves much to be desired, yet we have been impressed with the fact that the majority of the remnants of the old series represent highly siliceous and calcareous sediments and that those which could be considered as argillaceous are in the minority. It must be borne in mind, however, that igneous rocks are never far distant and rarely totally absent in a given case. After making due allowance, however, for the metamorphic changes we wonder where the meta-shales are; that is, if the term shale implies an argillaceous sediment as well as one possessing the characteristic structural habit of shales. The geologists
working in the Adirondacks have observed that the quartzose paragneisses of the Grenville are more prominent in the eastern areas, and that limestones characterize the western Adirondacks. The question naturally arises: Where did the argillaceous muds go? Where were they deposited? Now it is extremely improbable that we can give a satisfactory answer to this question here and at this time. It is very suggestive, nevertheless, that when the highly micaceous and hornblendic paraschists of the Hudson highlands and of New York City are considered to be Grenville in age, that in them (the Manhattan schist) we may perhaps find a partial answer to our question.

LAURENTIAN ROCKS

Under the name “Laurentian” we group some intrusive granites and tentatively some metamorphosed basic rocks, now ortho-amphibolites, which we name metadiorites. The granites we know to be later than the Grenville strata, and older than the Algoman intrusives. In the introductory discussion of the general stratigraphical table, we have made clear the impossibility of showing that these granites are older than the Huronian strata of the region of the Great lakes because we lack Huronian exposures in the Adirondacks. With this understanding and influenced by the close parallelism in lithological characters among the granites in both places we employ Laurentian and find it both convenient and useful.

Laurentian Granite

The granite here referred to as Laurentian has its best development in the northwestern Adirondacks rather than in the southern and eastern part of the mountains. Its recognition as a product of igneous activity antedating the Algoman eruptives is due chiefly to the work of Cushing. Although in the western Adirondacks the granite forms extensive batholithic masses which can be readily mapped, in the Ausable quadrangle it is intricately involved with the Grenville series so that its recognition is much more difficult. It has been found in several of the Grenville areas in the form of thin laminations which seem to have followed the bedding planes of the basal members of the old sediments. This peculiarity is characteristic of the Laurentian granite; it does not seem to have assimi-

lated the Grenville sediments but to have followed their lines of stratification or foliation when it was in a highly fluid condition. This process has resulted in a banded rock frequently having the appearance of a lit-par-lit injection gneiss, but there is a marked difference between Grenville rocks (usually quartzose) saturated by the Laurentian and those soaked by the Algoman granites. In the former case the bands, alternate ones of igneous and sedimentary materials, are distinct and are readily distinguished from each other especially under the microscope. The Grenville-quartz syenite (quartz nordmarkite) syntectic rocks, while clearly the product of similar processes, lack this distinct dual character and show a greater uniformity in compositional and structural habit. The Laurentian granite seems to have possessed greater fluidity but less chemical activity than the Algoman representatives.

The quartzose members of the Grenville offered much more favorable material for this process of soaking than the calcareous and hornblendic varieties, although it is difficult to understand why there is this selective peculiarity.

Four exposures of the Laurentian granite have been mapped; the largest block occurs on the northern slopes of Fordway mountain, clearly floating upon the Whiteface anorthosite. The latter rock cuts it by sending tongues upwards into it. In fact this district is especially interesting and significant in establishing the age relations of most of the rock units in the quadrangle. Several slabs of orthoamphibolite occur in the Whiteface anorthosite, as well as several inclusions of Grenville soaked by the Laurentian granite. Pegmatites of Algoman salic eruptives cut this combination of rocks which are also cut by a seven-foot dike of enstatite diabase.

Another area indicated upon the map is on the western slopes of Ragged mountain south of Ausable Forks. Here the Laurentian granite is soaking the basal mass of a thick block of Grenville quartzite, probably the upper Swede pond formation.

Another area of Laurentian granites shown on the map, is in the Trout pond area with its graphite prospect pits. The granite flanks the valley on the east side of an anticlinal fold of the Grenville rocks.

The fact that the Laurentian granite is so intricately involved with the Grenville, is apparently the cause of the failure of some geologists to recognize it as an igneous rock. If it exists in the Mount Marcy quadrangle it has not yet been recognized because few areas of Grenville are found there which are free from the
igneous influences of the Algoman eruptives. It would be very difficult to decipher the history of a rock produced by the combined saturations of the Laurentian and Algoman. It must be remembered that in this part of the Adirondacks it is only in areas of Grenville strata that the Laurentian occurs.

In appearance the Laurentian granite is a fine-grained, white to pale buff granite gneiss. It contains soda microcline, oligoclase-andesine, soda orthoclase and subordinate microperthite. In addition, it contains hornblende, biotite, together with the usual accessories, magnetite, apatite, zircon, pyrite, etc.

Petrographic examination of the feldspars shows that when they are microanalyzed and recast into their constituent components, the $\text{KAlSi}_3\text{O}_8$ is in excess over the $\text{NaAlSi}_3\text{O}_8$. This ratio is well-nigh universal for the Laurentian, while the soda granites of the Algoman rarely possess it and then only in extreme salic phases of the rock.

Thus the Laurentian is characterized by its potash content and its ability to penetrate along the bedding and foliation lines of the old Grenville sediments.

**Laurentian Metadiorites**

In the Whitehall quadrangle one of us\textsuperscript{38} has shown that there is a basic rock, which may best be described as a metadiorite or metamonzonite. It cuts the Grenville and the Laurentian granite in the form of a laccolith, but is itself cut by the Algoman quartz-nordmarkite. The laccolith is spread out on top of a thick bed of Grenville quartzite (the Swede pond quartzite) which had previously been soaked and saturated by the magmatic juices of the Laurentian granite. The rock of the laccolith is similar in some respects to the ortho-amphibolites of Keewatin (?) age, but differs from them in others. The Whitehall rock is not so basic, especially in the chilled border phases. Microperthite and quartz appear in addition to the ever present plagioclase. Hornblende, hypersthene and titaniferous magnetite are the chief dark components. Biotite is a common constituent of the chilled marginal phase.

Farther south, on the Saratoga quadrangle, upon the Flake Graphite Company's property this same type of rock appears again with the same age relations as given above. It cuts the Swede pond

quartzite which itself had been penetrated and affected by the Laurentian granite. The metadiorite is furthermore cut by the Algoman quartz-nordmarkite. Its laccolithic character and its medium basicity distinguish it from the other amphibolites of the region. In 1918 a Laurentian age was tentatively suggested for it because its relations to the older granite and later quartz-nordmarkite prove that it must be assigned to either the Laurentian or the Algoman igneous periods. If we consider the amphibolite as Laurentian, it is later than the granites; if we place it in the Algoman it precedes the quartz-nordmarkite. The only other known intrusives in this position are the anorthosites. On the whole, we prefer to place the metadiorite in the closing Laurentian. We do not conflict with geologic usage in assigning an igneous rock to the same period in which another is placed, although one is clearly younger than the other; and therefore as was done in the reference just cited, this metadiorite may be justifiably classified in the time interval represented by the Laurentian. Once this is done we have a succession in the Laurentian somewhat analogous to that of the rocks in the Algoman, where the quartz-nordmarkite is followed by the basic gabbros. The basic gabbros also exhibit marked chilled effects upon the older quartz nordmarkite.

Canadian Precambrian geologists have found in the Sudbury region a basic volcanic flow that appears to be of post-Laurentian, pre-Algoman age, a rock now known as Sudburite.39

It is significant to note that the Whitehall and Saratoga metadiorites are in the same taxonomic position as the Sudburite, and not very different from it in composition. We do not wish to imply that we definitely correlate the metadiorite with the flow of Sudbury but we would call attention to the close parallelism in position.

None of the ortho-amphibolites so far noted in the Ausable quadrangle can be definitely proved to be the equivalents of the metadiorites farther south because none exhibit field relations with the Laurentian granite. The only way in which correlations can be made is upon lithologic similarity, a method rendered difficult be-

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cause of the many unknown factors involved. If, however, this method is employed, the inclusions on the northern slope of Fordway mountain and the one in the cliff of Pokamoonshine mountain may be regarded as closely parallel in position with them and with the Sudburite of the great nickel district of Canada. The so-called "Woolen Mill" type of amphibolite, moreover, in the Elizabethtown quadrangle, with which the anorthosite exhibits some intrusive relations, may also belong to the same period (see p. 14).

THE ALGOMAN ROCKS

The original use of the name "Algoman" and its introduction into Adirondack geology have been mentioned in the outline of the stratigraphy on an earlier page. The name has proved extremely useful and furnishes a collective term for a series of related intrusive rocks embracing some of the most characteristic components of the Adirondacks. In the subsequent pages we corroborate what has been previously proved, that the anorthosites are the oldest; that they are followed by the syenite series of earlier papers; and that the basic gabbros are the latest. We make a departure in applying the name "nordmarkite" to some of the syenite series, emphasizing thereby their similarities with rocks described 30 years ago by W. C. Brøgger in the Christiania region of Norway.40 The syenite series embraces rocks of widely varying mineralogy, always with some quartz, often with a large quantity, and sometimes reaching the percentages in silica (and in quartz) which are well above the generally accepted lower limit of 65 per cent SiO₂ for granites. We believe that we have a transition to true granites, which are contrasted with the Laurentian granites, in being rich in soda as against the latter's potash. We have found one instance of inclusions of anorthosite in such a granite, the granite at the same time being apparently intrusive in the Grenville. The instance which is described and figured later adds the evidence of anorthosite xenoliths to that of protruding dikes of syenite which cut anorthosite, as already described by H. P. Cushing41; by one of us42 and by W. J. Miller.43

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40 Brøgger, W. C., Zeitsch. f. Krystallographie. 16:54, 1890.
Anorthosites

Nearly one-half of the quadrangle is covered by the anorthosites. They appear in two main areas: one along the western border with two main projections toward the central portion; and one along the eastern border with two main western projections, one in the Pokamoonshine hills and one along the southern edge. On the fringes of the projections and along the edges of the main areas themselves, the anorthosites become involved in relations of much complexity with the older Grenville strata and with the later intrusives.

As in other quadrangles in this portion of the Adirondacks, there are two types of anorthosite. The one, long known as the characteristic variety and more recently named by W. J. Miller, the Marcy type, consists in largest part of labradorite and in smaller amount of closely related plagioclases, of hypersthene, pale-green augite, rare brown hornblende, garnets and titaniferous magnetite. The rocks of the Marcy type in the Ausable quadrangle are commonly blue to green in color, but tendencies to reds and browns appear in the southeastern areas. The component crystals display quite universally the crushed and more or less saussuritized edges so characteristic of this rock in the Adirondacks. They are coarsely crystalline rocks, or were before they were affected by the rim-crushing. At times the component labradorites reach a very large size. In the exposures about a mile east of Jay village, crystals 6 by 6 inches and 4 by 8 inches have been noted. The maximum was shown about four miles east of Jay, where a record of one 15 by 20 inches was made. Granulated edges surrounded all the uncrushed centers of all these large components. As far as our observations go, granulation is nearly universal in the quadrangle. We find no extended exposures without it, such as appear in the southwestern portion of the Mount Marcy sheet. The labradorite exhibits the characteristic minute inclusions of rods and plates, presumably pyroxene and ilmenite. It occasionally manifests rather coarse microperthitic developments. The most frequent dark silicates are hypersthene and green augite. Brown hornblende is rarer. In the southeastern part of the quadrangle, as in the neighboring portion of the Elizabethtown, brown biotite appears in notable amounts. Garnet is an oft recurring component in all exposures.
The Marcy type of anorthosite has been so frequently described and is so simple in its mineralogy that it is not treated at great length here. Descriptions will be found with analyses on pages 27–37 in New York State Museum Bulletin 138, on the Elizabeth-town and Port Henry quadrangles, which lie to the south; and in the Museum Bulletin 229–30 on the Mount Marcy Quadrangle to the southwest.

The border facies of the anorthosite areas show a marked increase in the dark silicates, especially hornblende, a whitening of the feldspars, sometimes to a chalky hue, and the notable presence of titanite. A variety, named years ago by one of us "the Whiteface type" is thereby developed, which is in decided contrast with the blue or green feldspathic Marcy type. The feldspars show the same tendency to granulated and saussuritized edges and the change may go so far as to yield a chalky white mass of alteration products. In among the more or less altered feldspars the generally irregular hornblende, augite, aegirite-augite, garnet, ilmenite and titanite are set. Much irregularity of grain is exhibited here and there and gneissoid foliation is not infrequently developed. An analysis of the Whiteface type, prepared years ago for one of us and based on a specimen from Whiteface mountain in the Lake Placid quadrangle is given below.

<table>
<thead>
<tr>
<th>Whiteface type of Anorthosite, Summit of Mount Whiteface</th>
<th>Marcy type, Summit of Mount Marcy</th>
<th>Anal.</th>
<th>Anal.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>53.18</td>
<td>54.47</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>23.25</td>
<td>26.45</td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.53</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>FeO</td>
<td>1.82</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>2.60</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>11.18</td>
<td>10.80</td>
<td></td>
</tr>
<tr>
<td>Na₂O</td>
<td>3.97</td>
<td>4.37</td>
<td></td>
</tr>
<tr>
<td>K₂O</td>
<td>0.86</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>H₂O+</td>
<td>0.98</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>H₂O</td>
<td>0.15</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>0.45</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.98</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>tr.</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sp. Gr.</td>
<td></td>
<td>2.72</td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td></td>
<td>1.62</td>
<td></td>
</tr>
</tbody>
</table>

100.51 100.20
A comparative examination of these two analyses shows that the Marcy type is higher in silica, alumina and soda, as becomes a feldspathic rock, but that it is lower in iron oxides, magnesia and lime. When recast, we note a great increase in the dark silicates in the Whiteface type. Even when due allowance is made for possible variation in samples of each type which might be selected, we believe that the comparative contrasts shown by these two analyses will hold good in the large way. Samples could be selected on each side which would greatly accentuate them. The Whiteface type is a more basic border facies of the large anorthosite intrusive masses.

The increase in the dark silicates, the sericitization of the labradorite grains, and the common occurrence of titanite are particularly noticeable at the contact with Grenville sediments. The dark brown character of the hornblende is suggestive of actual assimilation of Grenville material by the anorthosite. It is our suggestion that the Whiteface border phase is in part due to differentiation and in part due to incorporation of foreign matters. In some exposures the former process is believed to be most important, while in other places in the area assimilation is called upon to explain the very irregular, blotchy, rusty-weathering nature of the rock. In such exposures the rock is markedly foliated giving the impression that the Whiteface anorthosite has derived its banded and gneissic character from the previously foliated Grenville sediments, that is by a gradual "soaking" and magmatic metasomatic replacement the structure of the older rocks has been superimposed upon the resultant syntectic Whiteface anorthosite. It is in such margins of the anorthosite that the xenoliths or inclusions of Grenville rocks are chiefly found. This observation lends support to the view here
entertained that the Whiteface phase is indeed a border phenomenon of the Marcy anorthosite. The borders of the inclusions are frequently corroded and the almost completely digested masses are all indicative of the magmatic activity of the anorthosite.

**Anorthosite pegmatites.** In their cooling and consolidating stages the anorthosites have given off some pegmatites as is customary with large intrusive masses. Two such instances have been noted about 2 miles east of Jay, along the belt which has yielded the excessively coarse crystallizations mentioned above.

### Syntectic Rocks

**Anorthosite — Grenville.** The results of magmatic assimilation are abundant throughout the quadrangle, for example, on the northern slopes of Big Crow and Little Crow mountains in the southwest corner of the sheet; and on the slopes of Baldface and Fordway mountains, the incorporated rock in this instance seeming to be the Grenville. In fact one of us in 1898 on Little Crow mountain found anorthosite containing graphite obviously derived from a Grenville original. The results of assimilation seem to be more pronounced on the summits of the mountains than in the valleys. When such syntectic rocks are found at low altitudes there is reason to believe that they represent blocks that have been faulted into their present positions. We infer that the level of the summits represents the approximate original position of the base of the Grenville strata and that the invading anorthosite has soaked and dissolved the basal members of the series. The syntectic rocks vary in composition and in texture according to the kind of original rock, whether old shales, sandstones or calcareous sediments, according to the degree of digestion. Sometimes the amount of the two rocks is nearly equal, resulting in a pronounced hybrid easy to recognize although difficult to describe. W. J. Miller, in the Lake Placid quadrangle, refers to them as Grenville-anorthosite mixed gneisses, which is another mode of expressing the same thing.

The rocks of the Grenville series are not the only ones involved syntectically with the anorthosite; there are also quartz nordmarkite-anorthosite hybrids within the area. As these have been produced by the assimilation of the anorthosite by the quartz nordmarkitic series, a detailed description will be deferred until the latter are discussed.
Intrusive Nature of the Anorthosite

The anorthosite has, until quite recently, been regarded as an intrusive in the ordinary sense. N. L. Bowen from a physical-chemical study of the albite-anorthite series of solid solutions reached the interesting conclusion that the anorthosite had never been molten as such. He recognized that the anorthosite is essentially a plagioclase (usually labradorite) rock. When the solution theory is applied to rocks consisting essentially of one mineral, the question arises whether they ever were hot enough to be molten per se. This led him to search the literature to see if a denial of the molten character of the anorthosite would violate any recorded fact observed in the field. Bowen did not find any reference that would be incompatible with his supposition. His conclusions based upon experimental work can not be ignored by the Adirondack geologist, and consequently we have attempted to keep Bowen's view in mind while engaged in mapping the Ausable quadrangle during the last season spent in the field.

Bowen explains the formation of the anorthosite by the accumulation of plagioclase crystals precipitated from solution in a "mixed magma" probably gabbroic in composition. He pictures a huge laccolith invading and splitting the overlying Grenville series; and differentiating into an upper layer of syenite-granite (quartz nordmarkite); a bottom one of gabbro; and an intermediate zone of anorthosite. The suggestion of a laccolith is a new conception and may furnish the explanation of some of the obscure problems of the Algoman. The writers, however, take exception to Bowen's view. We have not found any suggestion in the field that there is a close genetic relationship between the quartz nordmarkite and the anorthosite; on the contrary, we have observed syntectic rocks produced by the penetration, "soaking," lit-par-lit injection and assimilation of the anorthosite by the quartz nordmarkite intrusives. Xenoliths (inclusions) of Grenville rocks, within the anorthosite, exhibit corroded margins demonstrating that the anorthosite was indeed hot enough to dissolve the surfaces of such blocks. The rock surrounding such blocks is normal anorthosite, sometimes of the Mount Marcy but more frequently of the Whiteface type. It is not gabbroic in character. Similarly xenoliths of anorthosite occur in the quartz nordmarkite (for example 2 miles west-northwest of Lewis). It is much more easily conceivable that these blocks con-

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sist of previously solidified anorthosite and were caught up by the invading quartz nordmarkite rather than that they were formed by the settling of plagioclase crystals which were forced upwards into the quartz nordmarkite. Bowen’s hypothesis is based upon the assumption that the anorthosite is essentially a one mineral rock consisting of labradorite. This mineral becomes completely melted between 1440° and 1480° C., a temperature considerably higher than that of most magmas. But the anorthosite is by no means a homogeneous mass of plagioclase. Most of the rock contains from 2 to 5 per cent of other minerals, while specimens which carry 5 to 10 per cent are very common. Even 20 per cent is not unusual. Whether these percentages are sufficient to lower the temperature of the entire melt is not known, but the fact is worthy of consideration. The anorthosite as now found does not represent the composition of the original magma. The associated gases and liquids escaped during solidification. It is well known that such volatile matters appreciably lower the fusion temperatures of magmas which are mutual solutions. Bowen did not find, in a visit to the Adirondacks and to Quebec, any evidence of pneumatolitic action on the part of the anorthosite. Within the limits of the Ausable sheet we have found two anorthosite pegmatites, petrographic description of which is given in another place, which suggest that such gases and vapors were not lacking. The current supposition is that only granites produce pegmatites. It is true that they are the most productive of such off-shoots, but many other igneous rocks are capable of forming them. Even the more basic rocks, such as the gabbros and norites, also produce them. Occurrences of the latter have been noted in the Willsboro and in the North creek quadrangles. These observations lead us to suggest that the anorthosite contained sufficient amounts of ferro-magnesian minerals and mineralizers to be fluid at normal magmatic temperatures, and consequently we adhere to the older conception of fusion.

The rejection of the theory that the anorthosite was never molten as such does not militate, however, against Bowen’s suggestion that the rock is laccolithic rather than batholithic. We do not know which it is. Mount Marcy itself furnishes a section of nearly 4000 feet of fairly clean anorthosite. If the body is laccolithic it must have been of at least that thickness. A clarification of this problem is necessary in order to arrive at the true conception of the relation

of the Whiteface anorthosite to the normal Marcy type. If the anorthosite is batholithic then the Whiteface is the outer chilled marginal phase of the rock. If, however, it is laccolithic the Whiteface is the upper chilled border. We are obliged to forego any definite conclusion regarding the large structural character of the anorthosite mass.

**Syenite Series**

The rocks of the syenite series are widely but irregularly distributed in the quadrangle and are intricately involved with the anorthosites. The best, freshest and most typical green specimens are afforded by the quarries which have been opened on both sides of the east branch of the Ausable river a mile south of Ausable Forks. The stone is a beautiful dark green variety, massive and unaltered. At the quarries the glaciated surfaces which have been exposed by the removal of the sands and gravel, have a dense, white skin of alteration which is characteristic of the rock. Where, however, as is often the case in the ledges of the higher mountains, the outcrops have been long exposed to the weather, the rocks appear as crumbling, rusty varieties, whose outer crust one has to pound away with the hammer, often for several inches, in order to expose the fresh green rock within.

When the areas of the syenite series, as colored on the map, are studied with a view to structural interpretation, one must conclude that the molten rock came up through the Grenville strata, the Laurentian granites and the anorthosites, in stocks and irregular intrusive masses whose largest examples may reach 10 to 20 square miles in area. Faulting and the ever-present mantle of sand and gravel serve to conceal the details of relationships which we often wish we could see.

In the stratigraphical table on p. 9 and in the remarks upon it, we have introduced the name nordmarkite, or quartz-nordmarkite, which was originally applied by W. C. Brögger to rocks near Christiania, Norway. That the syenite series of the Adirondacks presents close parallels with Norwegian rocks has long been known. In describing the interesting exposures near Loon lake, which contributed in a most important degree to establishing the intrusive nature of this, at that time, recently recognized separate group of

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46 Cushing, H. P., Jour. Geol. v. 25, p. 506.
47 As emphasized by Miller, W. J., Bull. Geol. Soc. Amer., v. 29, p. 399.
igneous rocks, H. P Cushing emphasized the parallels in mineralogy and chemical composition with those described by W. C. Brøgger. In the original monograph,\textsuperscript{48} Professor Brøgger, had before him a series of richly alkaline igneous rocks, ranging from an alkali-rich extreme of nephelite syenites (laurdalites) through quite basic syenites (laurvikites), more acid quartz-bearing syenites (akerites); to still more acid quartz syenites (nordmarkites), soda-granites and normal granitites. Professor Cushing has compared the Adirondack rocks with the akerites\textsuperscript{49} and in many respects the parallel is very close. As in the Adirondack syenitic rocks, the Norwegian varieties are notably rich in soda, so that both give rise to soda-rich feldspars, pyroxenes and amphiboles. In contrasting the akerites and nordmarkites, Professor Brøgger states on page 55 of his monograph, after a table of four analyses of nordmarkites, that the nordmarkites are higher in silica on the average than the akerites. On looking up the analyses of akerites we find the typical case SiO$_2$, 58.58 and the range 56.79 to 62.52; whereas the nordmarkites afford SiO$_2$, 60.45 to 66.39. Akerites have combined Na$_2$O and K$_2$O, about 6 to 10 per cent; nordmarkites 12 to 13 per cent. Akerites have CaO, 3 to 5 per cent; nordmarkites, 1 to 2 per cent. Akerites have combined iron oxides and magnesia, 8 to 12.5 per cent; Nordmarkites, 3.5 to 5 per cent. The mineralogy of the two groups exhibits corresponding contrasts. There are more dark silicates in akerite, and fewer in nordmarkite.

The analyses published by Professor Cushing of syenitic rocks from the Adirondack region, range in SiO$_2$ from 59.7 to 65.65, the Loon lake sample having 63.45. Combined alkalies range from 7.58 to 10.31; lime 2.47 to 4.05, the 2.47 being from the Loon lake analysis; iron oxides and magnesia 4.14 to 11.53. Thus the silica favors the nordmarkite ranges, while the alkalies, lime and other bases are nearer the akerite ranges. Obviously in the Adirondacks we have both akerites and nordmarkites; but as we are compelled to trace in the Ausable quadrangle a transition from the typical green syenites (perhaps akerite) to rich quartz bearing varieties and soda-granites, we have used nordmarkite, or quartz-nordmarkite by preference, because the greater number of our rocks fall within its limits.


Nature and comparative petrography of the syenitic (nordmarkitic) series. Ever since Smyth,\textsuperscript{50} Kemp,\textsuperscript{51} and Cushing\textsuperscript{52} recognized the igneous nature of these green granitic rocks of the Adirondacks they have been described and mapped as belonging to the syenites. The chemical analyses and petrographic descriptions, however, show that considerable free quartz is almost invariably present, and demonstrate passage varieties to and into the granites.

The feldspar has long been known to be microperthitic, especially in the dark colored varieties. In these the pyroxene under the microscope is emerald green and is considered to be soda bearing, justifying the term aegirite-augite. This mineral undoubtedly is chiefly responsible for the general color of the rock. With an increase in the potash content of the feldspars and a greater amount of quartz the rock becomes lighter in color and eventually passes into a pink soda granite. In the strict petrographic sense these rocks are members of both the syenite and granite families, but in view of the presence of pyroxene (instead of hornblende and mica) the low quartz varieties have been called “augite-syenites.” In spite of this distinguishing term the geologist not familiar with the region would not appreciate the fact that they were 

\textit{high in soda}. It would be possible to employ the term “soda” and thus speak of “augite soda syenites.” As most of the syenitic rocks within the quadrangle, however, are quartzose such an expression as “augite quartz soda syenite,” while explicit in its meaning, would be unduly awkward. Consequently we have attempted to find a more satisfactory term to be applied to the syenites here described and mapped. The purpose has been three-fold: to give a more satisfactory name, indicative of the true nature and composition of the rocks; to show the similarity with other Precambrian areas of North America and Scandinavia; and to have a name that will be distinctive from the Laurentian series of intrusives.

Comparisons of the syenitic rocks of the Adirondacks with similar ones of Norway, Sweden and Lapland have been drawn by Cushing,\textsuperscript{53} and Newland.\textsuperscript{54} The former pointed out the similarities

\textsuperscript{54} Newland, D. H., N. Y. State Mus. Bul. 149, p. 110.
of the Adirondack syenites with the Norwegian akerites. While some of our rocks could be referred to as such, the majority of them are more akin to the nordmarkite series. Our departure from the comparisons drawn by Cushing is partly due to our increased knowledge of the rocks of northern New York as the result of recent field work.

If we compare Cushing's basic syenite from Raquette Falls and Tupper Lake, Franklin county, with laurvikites from Norway, Canada, and Madagascar, we are impressed with the close similarity of their forms as recast from the chemical analyses. Kemp gives the following definition of laurvikite:

“A variety of augite-syenite that contains natron-orthoclase [anorthoclase] as its chief feldspar and most abundant mineral. The other components are rare plagioclase, pyroxene, biotite, barkevikite or arfvedsonite, olivine” and other accessories. The similarity is not so readily seen on this basis (mode) unless the reader grants the genetic and compositional kinship between anorthoclase and microperthite, for it is believed that the microperthite found in these rocks possesses almost the same chemical composition as the anorthoclase, cryptoperthite and microperthite of Brögger's laurvikite. The description of the Canadian laurvikite reads as though it were an Adirondack representative. “The dark augite syenite (has) . . . the same general appearance . . . as hand specimens of the Norwegian laurvikite . . . The feldspar . . . is chiefly a microperthite . . . Pyroxene is the chief dark mineral . . . and is undoubtedly one of the aegirine (aegirite) augite series.”

However, the majority of the Adirondack syenitic rocks contain considerable quartz and thus the term “laurvikite” is too restricted. In the nordmarkite of Brögger we find a term that seems to apply to these rocks of a more acidic character than the basic border differentiates.

Kemp gives the following definition for nordmarkite: “A variety of granite rocks consisting of orthoclase, some oligoclase, more or less microperthite, quartz and subordinate aegirite.”

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60 Alling, H. L., Mineralogy of the Feldspars. Jour. Geol., v. 29, 1921, p. 291.
Figure 5  Diagram showing per cent composition by weight of Laurvikites. Double column diagrams show: first column, mode; second column, norm calculated from chemical analyses.


4 "Laurvikite." Same reference as no. 3.


6 "Laurvikite." Nötterö, Norway. Same reference as no. 5.


A study of the norms of nordmarkites from Massachusetts,\(^{63}\) Vermont\(^{64}\) and Quebec\(^{65}\) show an average of 11.3 per cent quartz, while those specimens that have been called quartz nordmarkites have a quartz per cent of 13.68, a value which agrees with the


\(^{65}\) Dresser, J. A., Amer. Geol. v. 28, 1901, p. 29.
rocks from the Ausable quadrangle. Thus for our purpose we can classify the syenitic-granitic rocks as follows:

<table>
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<tr>
<th>Quartz per cents</th>
<th>Soda-rich</th>
<th>Potash-rich</th>
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<tr>
<td>0-5</td>
<td>Laurvikite</td>
<td>Syenite</td>
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<td>5-10</td>
<td>Nordmarkite</td>
<td>Quartz syenite</td>
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<tr>
<td>10-15</td>
<td>Quartz nordmarkite</td>
<td>Syenite-granite</td>
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<tr>
<td>Over 15</td>
<td>Soda granite</td>
<td>Granite</td>
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Figure 6 Diagram illustrating the composition of various Nordmarkites. Double column diagrams show: first column, mode; second column, norm calculated from microanalyses. Single column, norm from chemical analyses.

4 "Quartz syenite." Quarry southeast end of Lake Placid. Miller, W. J. Idem.
In classifying the Adirondack rocks after this manner, we would consider Cushing's Raquette Falls and Tupper Lake specimens as laurvikites and the green syenitic rocks of the Ausable Forks area as ranging from quartz nordmarkites to soda granites. In this connection it is especially interesting to note Daly's\textsuperscript{66} description of the nordmarkite from Wolf Hill, Gloucester, Essex county, Mass. "The rock is a handsome dark green syenite . . . Microperthite is by far the most abundant constituent and with it are associated . . . soda-orthoclase, [soda] microcline and plagioclase." The microperthite is an intergrowth of soda orthoclase and a plagioclase, albite-oligoclase ($\text{Ab}_2\text{An}_1$) "Generally . . . the proportion of potash to soda is about $1:1$.

The quartz nordmarkites of the Ausable sheet are dark bottle green in color; a characteristic that the geologists use as a means of distinguishing the "syenites" from the quartzose phases of this series. Quantitative petrographic study, however, questions the reliability of this method in all cases in as much as many of the dark green varieties are rich enough in free quartz to cause the rock to be classified in the soda granite group. Under the microscope the typical green quartz nordmarkite consists of microperthite; intergrowths of soda-rich and potash-rich feldspars. The ratio the two phases present in the perthite is often $1:1$, though more frequently the soda phase is in excess; thus the mineral deserves the little used term "antiperthite."

Although the term microperthite is commonly used in a qualitative rather than in a quantitative sense, the common variety contains the potash component in excess over the soda and consequently the term has come to mean an intergrowth of potash and soda feldspar, rich in potash. Antiperthite is used to mean a similar intergrowth but rich in soda. The soda phase is albitic oligoclase to andesine. Sometimes the plagioclase occurs in separate grains.

The pyroxene is brilliant grass to emerald green; undoubtedly soda bearing. It possesses a faint pleochroism. Hypersthene and hornblende are the other common ferromagnesian minerals. In certain phases of the quartz-nordmarkites near Ausable Forks, such as that from the Ausable Forks Granite Company's quarry, the rock contains small amounts (a mere trace to 3 per cent) of a mineral whose general appearance and optical properties are suggestive of olivine. The presence of such an orthosilicate in a rock

GRANITES

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Figure 7. Diagrams illustrating variation in composition of soda granites. Percentage by weight.

1-6 Ausable quadrangle. 7-9 Other Adirondack granites. 10-12 Other localities.

Double column diagrams show: first column, mode; second column, norm calculated from microanalyses. Single column diagrams, norm from chemical analyses.

1 Quarry on southwest shoulder of Ragged mountain, 7 miles south of Ausable Forks (Specimen K-254).
2.8 mile north northeast of Ausable Forks (Specimen 1086).
3.8 mile north of Ausable Forks (Specimen 1087c).
4.1 mile northeast of Ausable Forks (Specimen 1086a).
5.7 mile northeast of Palmer hill (Specimen K-216).
6.4 mile southeast of Ausable Forks (Specimen 1098).
7 "Granite." Lake Placid quadrangle, from gorge at High Falls, Miller, W. J., N. Y. State Mus. Bul. 211-12.
10 Soda granite from Clove mine. Hudson Highlands. Slide lent by R. J. Colony.

with 13 per cent of free quartz is a most unusual one. Its crystalline habit is apparently orthorhombic and it has the general characteristics of forsterite but the index of refraction is too high for this mineral. The value of the axial angle is also too high, being
approximately 100° (2V). This would suggest a high iron content like hyalosiderite or hortonolite but the mineral is positive in optical character. We are unable to arrive at a reasonable conception of its composition.

Besides the unusual "olivine" the same rock contains primary fluorite in small grains showing well-developed crystal borders and apparently occupying normal relations to the quartz and antiperthite. The "olivine" and fluorite are not limited to the Ausable Forks granite quarry rock; the "olivine" occurs in rocks on the south shoulder of Ragged Mountain in marginal phases of quartz nordmarkite. The fluorite also occurs in the more acid differentiates to the north, culminating in a fluorite granite on Palmer hill where the mineral makes up 25 to 30 per cent of the rock. The quarry on the southern slopes of Ragged Mountain shows an extreme "basic border phase of the intrusive mass. It is characterized by fine grain, and a larger percentage of the dark constituents, with reaction minerals like garnet... along with the increase of the ferromagnesian mineral. There is a gain also in the lime-soda feldspar which shares importance with the alkali varieties." This rock is therefore a soda-rich quartz monzonite, but its development as a border phase is too local in extent to be mapped as such.

**Soda granites.** The more acidic phases of the Algoman intrusives are grey to pinkish in color usually failing to exhibit the green color of the nordmarkititic ranges. The increasing quartz content of the rocks is accompanied by the gradual passage of the antiperthite into more potassic varieties which become so low in the soda component that it no longer exists as a separate phase in the form of intergrowths, but occurs as a constituent in the soda microcline. The aegirite-augite and hypersthene gradually disappear; their places being taken by hornblende and, in the slightly porphyritic phases of the rock, by biotite.

In addition to the usual and normal soda granite of the Ausable sheet there is the ore-formation granite. Newland says:

The rock is an interesting type, as it belongs to the true [soda] granites, being composed of [alkali] feldspar and quartz in normal proportions, but on the other hand contains no dark silicates of the mica, amphibole or pyroxene families. In the place of such min-

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erals, however, it carries a large amount of magnetite which ordi-
narily is a very minor constituent of granite. The mineral con-
stitutes about fifteen per cent of the entire rock.

Although there is every reason to believe that this granite is but
a differentiate of the same magma, or magmas, that gave rise to
the quartz-nordmarkites and the other soda granites, yet in its nor-
mal development it is so distinctive either under the microscope or
in the field that it has been thought worth while making the separa-
tion from the other types of granitic rocks within the quadrangle.
It is quite possible that this is the rock that W. J. Miller has called
the "Lyon mountain granite" on the Lyon mountain sheet and in
part the "granite porphyry" on the Lake Placid quadrangle.

The ore formation granite and the country rocks of many of the
Swedish magnetite deposits have been compared by Newland.  

Rocks of syenitic composition are the prevailing ones associated
with the magnetites of Lapland . . . Quartz is a variable com-
ponent. Magnetite, diopside, hornblende and biotite are the chief
dark constituents . . . The general impression gained from the
cursory field study and later comparison of the country rocks indi-
cates close resemblances to the ore bearing syenitic gneisses in the
northern Adirondacks, particularly Lyon Mountain, Palmer Hill
and Arnold . . . Mineralogically and chemically the two series
are very similar. Both are characterized by high soda percentages
[the italics are ours] which place them in the soda-syenite class, the
prevalence of perthitic and acid plagioclase feldspars, and by the
relatively large amounts of free iron oxide [ferrous ferrate] in the
form of magnetite.

In the field the ore-formation granite lacks the abrupt and steep
joint faces exhibited by the normal soda granite and presents more
rounded knobs. The ore-formation granite is composed of soda
microcline and potash-rich microperthite, usually the former domi-
nating in amount although the reverse is not uncommon. Albite
to oligoclase occurs as an accessory to the magnetite. Titanite and
a little aegirite-augite occasionally are found. Zircon, apatite,
pyrite and fluorite complete the list.

The rock is exposed in the northern part of the quadrangle and
in the form of a tongue extending southward in the valley of Trout
pond past Copperas pond to Ore Bed pond. It constitutes the
wall rock of the magnetite ore bodies of Palmer and Arnold hills.

Petrogenetic Relations of the Algoman Granitic Rocks

Cushing and Miller have emphasized the extent to which all gradations from basic to acid types of the nordmarkite-soda granite rocks exist through the process of differentiation. In the nomenclature here employed they range from laurvikites to soda granites. In the laurvikitic phases, usually marginal, the feldspar is prevailingly oligoclase-andesine and antiperthite, while the ferromagnesian constituent is aegirite.72

The passage to quartz-bearing representatives is marked by the plagioclase becoming more and more albitic and by its decrease in amount, while the microperthite passes from the high soda to high potash ranges. This simple change in the composition of the feldspars is complicated by the manner in which the potash, soda and lime feldspar components (as given by a norm analysis) are actually distributed in the feldspar phases present in the rock. Frequently it happens that in a low lime bearing rock the potash and the soda components are in the form of antiperthite, while in another rock, of similar or of identical chemical composition, the feldspar components are much more separated and occur as soda microcline and albite-oligoclase. In studying the perthitic representatives the high soda character is not so striking as in the latter case. This leads to the apparent conclusion that the former is more acidic than the latter while the truth is that there is no difference in their chemical composition but merely a textural one. This matter should be kept in mind in making comparisons between these rocks.

If the feldspathic components are separated, either by recasting a chemical analysis or by quantitative microscopic determinations, the nordmarkite rocks are shown to contain more soda feldspar than the potash component, but the potash constituent becomes nearly equal in amount in the soda granites. In a few instances,

72 We should not fail in the discussion of the syenitic rocks to note the similarity which the pyroxene-bearing variety presents to the mangerites of C. F. Kolderup, which are found in association with the anorthosites of western Norway, as described in Die Labradorfelsen des westlichen Norwegens, Bergens Museums Aarbog, 1903, 102. The mangerites are granitoid rocks consisting essentially of microperthite and augite. By dynamic metamorphism, the augite may pass into hornblende and biotite. Gneissoid structures are also induced. Quartz-mangerites represent acid phases. The parallel with the rocks of the Adirondacks has already been remarked by H. P. Cushing in Geology of the Northern Adirondack Region, New York State Museum Bulletin 95, p. 338, 1905. The close relationship of mangerites to laurvikites can not escape any student of petrography who reads the original descriptions with the desire to emphasize large similarities rather than to magnify minor differences. As laurvikite, akerite and nordmarkite have priority of publication by 13 years, we have used them in preference to mangerite.
however, in abnormally quartzose rocks the potash feldspar exceeds the soda. This observation is of limited use in distinguishing the Algoman granites from the Laurentian representatives. In speaking of the latter Cushing says "The character of the feldspar is quite different from that of the syenites [of Algoman age] . . . and this constitutes the main [petrographic] difference between this rock [Laurentian] and the syenites."

The observed varieties of the Algoman granitic rocks are considered to be due to magmatic differentiation; the chief factor being fractional differentiation, through crystallization. This process is complicated, however, by magmatic assimilation. That the latter has taken place can not be denied. In fact, it is commonly recognized as a necessary element in the petrographic concepts pertaining to the Adirondacks.

The nordmarkite intrusives are involved with all varieties of the older rocks of the region. These igneous rocks invaded the Grenville sediments from below, forcing their way into the country rock by a limited amount of magmatic stoping, and gathered in blocks which in the hotter portions of the magma were completely assimilated, producing hybrid types or syntectic rocks. Along the margins the blocks of Grenville rocks are still to be seen as included xenoliths. The foliation of these syntectic rocks produced by the contamination of Grenville rocks is especially marked in the Ausable quadrangle. We have been greatly impressed with the parallelism of the foliation of the syntectic rocks with that of the Grenville in the southwestern corner of the sheet. We have traced the gradual passage from normal quartz-nordmarkite to the syntectic rocks and thence into biotitic, hornblendic varieties of the Grenville series. Our belief is that the foliation of the old sediments, which took place before the intrusion of the quartz-nordmarkite, has been superimposed upon the igneous rock. The syntectic rock seems to have been produced by a gradual process of lit-par-lit injection on a very delicate scale and by slow dissolving of the Grenville materials. The resulting rock is rusty in appearance, having the general mineralogy of a syenite. With the conception that the intrusives of the Adirondacks have actually assimilated the country rock it is now possible to understand these rusty gneisses. The hornblende in the syntectics is apparently of a different composition from that of the quartz nordmarkite or soda granite. Some of the syenite that has been mapped in the past is in all probability a syntectic of the soda granite and Grenville rocks.

The quartz nordmarkite-soda granite series has assimilated anorthosite as well. This is especially noticeable where the nordmarkites invaded areas of anorthosite. This syntectic is readily recognizable, possessing the character and composition of both the rocks. In the quarry half a mile east of Stickney Bridge the rock shows the general character of the quartz nordmarkites in that it is distinctly green, but exhibits, even to the unaided eye, crystals of steel blue labradorite, usually as augen. Under the microscope the feldspars show great variation in composition and in texture. One slide showed labradorite, some of which was untwinned, and oligoclase which was holding blebs of soda microcline. The latter is antiperthite. Another slide showed labradorite crystals containing eutectic inclusions of a potash rich feldspar. The ferromagnesian minerals in a similar manner exhibit interesting variations from the normal. Hypersthene, aegirite-augite and rich brown biotite occur. Garnet rarely fails and is often accompanied by primary calcite. Magnetite, rutile and martite complete the list. Without the conception of assimilation this rock would be difficult to understand; it probably would be classified as an extreme basic phase of the nordmarkite or laurvikite of the region. In the Lake Placid quadrangle to the west this syntectic rock has been called by Miller the "Keene gneiss," from the type locality of Keene Center. Other areas of the quartz nordmarkite-anorthosite syntectic can be seen represented upon the map.

The significance of this syntectic rock is that the quartz nordmarkite intrusive was extremely active in assimilating previously formed rocks. It seems to have assimilated the anorthosite in a much more thorough manner than it did the Grenville rocks. This can be explained by assuming that the anorthosite was still hot, although not molten, when the quartz nordmarkite entered. In this case there was no marked chilling effect upon the magma as was the case with the cold Grenville rocks.

**Granite.** Across the highway to the west of the Grenville limestone exposure, slightly less than 2 miles north of west from Lewis, there is an exposure of gray gneissoid granite, with four or more xenoliths of anorthosite, which were first noted by one of us in 1899. At the time the xenoliths were puzzling, since the gneissoid granite was involved with Grenville strata. In the light of the results since worked out in the Adirondacks we interpret the granite as a member of the Algoman nordmarkitic rocks, and as having picked up the older anorthosite fragments as it rose through the anorthosites in its
passage upward. As illustrated in the accompanying sketch (figure 8) the xenoliths are rounded and corroded. The larger one has influenced the development of pegmatite near it, as is sometimes to be noted in the case of xenoliths in granite, and garnets are also to be observed in the granite near it, probably from the absorption of anorthosite, a rock much richer in lime than the granite itself. One of the neighboring xenoliths had a garnet border undoubtedly a reaction rim on a large scale and much the same in origin and character as those described in a later page from microscopic observations of the basic gabbros.

**Basic Gabbros**

The basic gabbros, the latest members of the Algoman, appear in fifteen separate exposures, the largest of which is on the southern slope of Jay mountain. The others reach, at most, a square mile in

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area and frequently constitute the summits of hills, for which feature their resistant character is responsible. Quite invariably, fresh specimens of rock can be obtained from the exposures, and even when they are studied in thin sections, alteration from weathering plays a small part. In this quadrangle as elsewhere in the eastern Adirondacks these rocks seem to favor chimney-like forms of outburst and to have stoped or fused rounded conduits to the upper world.

In most places we have only the stumps of old masses, since the texture is invariably that of a deep-seated rock, and we regard most of them as plugs or pipes, circular or elliptical in horizontal cross section. The recognition, however, of laccolithic forms of gabbro in the Bolton quadrangle\(^75\) lends color to the supposition that some of the bodies within the Ausable sheet assumed a mushroom form. In the southeast central portion of the sheet occurs a narrow mass from an eighth to a quarter of a mile in thickness but 3 miles long. One interpretation is that it represents a dike, while another is that it is the edge of a tilted laccolith. It may be that the large mass of gabbro on Jay mountain is a laccolith partially unroofed by erosion.

The gabbros have often been described in earlier papers or monographs. Their essential characters were given in the first paper in which their occurrence in the region was announced,\(^76\) so that it is only necessary for the local record to give a condensed summary of their characters here.

They are black or dark green rocks, which when not crushed and sheared into gneissic foliation, often exhibit visible tabular outlines for the dark green plagioclases. They are richly provided with dark silicates and with irregular bits of titaniferous magnetite. They almost always have a pinkish cast, because of the streaks of tiny garnets with which they are richly provided. Under the microscope enough hypersthene frequently, although not invariably, appears with the universal green augite to make them norites, but we also find associated in notable quantities brown hornblende and red-brown biotite. The labradorite favors a broad, rodlike habit and is repeatedly twinned. The crystals are customarily rendered opaque in the central portions by multitudes of minute inclusions of


pyroxene dust and very minute spinels. The outer rims are water clear. The titaniferous magnetite, the occasional olivine and even the pyroxenes are prevented actual contact with the labradorite, by reaction rims of garnet. Often one sees the inner nucleus of magnetite or olivine surrounded by a zone of brown hornblende, red-brown biotite, green augite, pink and green hypersthene, and finally pink garnets in concentric arrangements of greater or less perfection. The garnets also finger out into the labradorite and at times seem to favor special lamellae in the multiple twin. A careful study of similar garnet rims which appeared in a coarsely crystalline anorthosite was prepared by Max Roesler for the New York State Museum Bulletin 229–30 on the Mount Marcy quadrangle. Doctor Roesler gives a chemical analysis of the garnets.

An instructive insight into the nature of the garnet reaction rims or coronas of the gabbros was obtained from a petrographic study of thin sections cut from the chilled border of the large round mass of gabbro in the western slopes of Fordway mountain in the northeast corner of the map. Here the gabbro has cut through the ore-formation granite exhibiting a sharp contact which is exposed for a quarter of a mile, enabling a detailed study of the effects of chill. Slides were prepared from specimens collected at measured distances from the granite. Under the microscope it was found that the chilled border within an inch of the line of contact was very fine grained and contained plagioclase ranging from basic labradorite to bytownite, usually not twinned. The plagioclase was accompanied by green slightly pleochroic hornblende. The rock showed no corona structure, garnet, augite and hypersthene being absent. A foot away the hornblende began to be displaced by pyroxenes, the former assuming a different composition as shown by the change of color to a pale brown. Garnet commenced to appear with faintly developed coronas. Ten feet distant from the contact the plagioclase was acid labradorite or basic andesine, the pyroxenes, both augite and hypersthene, dominated over the hornblende, while the garnet, in large amounts, was characteristically involved in the coronas.

The interpretation of these observations is that the chilled border represents the frozen magma of an early stage, perhaps differing somewhat from the parent magma through differentiation due to chill. The plagioclase is more basic than that which crystallized later; the hornblende contains less ferrous iron and there are no coronas. These garnet reaction rims consequently were formed.
during the later stages of crystallization. The garnet is not due to assimilation, neither is it formed of materials introduced into the magma from without. Garnet, however, is not a normal rock constituent. It is the product of reaction within the magma as it solidified. Physical chemists would speak of peritectic reaction\(^{77}\) between solid phases and the still unfrozen liquid melt. It is our belief, therefore, that the coronas which make the gabbros, or more properly the norites, the object of so much petrographic interest are thus the product of magmatic processes which operated during the later stages of crystallization. They are perfectly normal results of peritectic reaction between solid and liquid solutions.

In the Elizabethtown and Port Henry quadrangles, which lie respectively south and southeast of the Ausable, the basic gabbros contain notable bodies of titaniferous magnetite\(^{78}\) but we have found no openings upon ores of this character in the Ausable.

**SUMMARY ON THE AGES OF THE GRANITES**

Cushing in 1896\(^{79}\) described in the following words a belt of granitic gneisses extending "through Northern Clinton and Franklin counties adjoining the Potsdam boundary . . . To the northward in Canada there are great stretches of country occupied by similar rocks, and the name Ottawa gneiss is there given to the formations. Uncertainty as to the equivalency of the two led me [Cushing] some years since, to propose the name ‘Dannemora formation’, the name to serve unless equivalency with the Ottawa gneiss can be shown, in which case that name should be adopted. Since, however, possible confusion with a noted Scandinavian locality may result, the name Saranac formation is suggested to replace it.\(^{80}\) Subsequent work has shown that there are certain granitic gneisses in the Adirondacks that can be confidently correlated with the Ottawa gneiss. The latter has, however, been assigned to the more general time unit, the Laurentian. In addition to these old granitic rocks definitely included in Cushing’s Saranac series there are members of the later intrusions that are here referred to as Algoman. In as much as Newland\(^{81}\) states that the granitic gneisses

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\(^{77}\) Hoyt, S. L., Metallography, pt. 1, 1920, p. 22.


\(^{80}\) Cushing, H. P., N. Y. State Mus. Bul. 95, 1905, p. 299.

\(^{81}\) Newland, D. H., N. Y. State Mus. Bul. 119, 1908, p. 16.
which constitute the wall rocks of the Lyon mountain, Arnold hill and Palmer hill magnetite deposits are to be assigned to Cushing's Saranac series, there may arise some confusion in regard to the age of the country rock of the iron ores. Miller\(^{82}\) states that the "Lyon mountain granite is perhaps the most conspicuous member of Cushing's Saranac formation." This implies, as the natural interpretation, a Laurentian age. On the other hand, we have been more and more forced to the conclusion already reached by Newland, that the undoubted syenitic (nordmarkitic) series of Algoman age grades inseparably into the ore bearing granite, and consequently we view the country rock of the magnetite deposits as later than the Laurentian (Saranac, Ottawa) granitic gneisses. It is out conclusion that the ore-bearing granites of Palmer hill are magmatic differentiations from the parent mass which also yielded the syenitic (quartz-nordmarkitic) series. In a region heavily covered with Pleistocene deposits, and in the case of transitional phenomena which shade gradually into one another, an incontrovertible demonstration is not easy, but we give the above conclusion as the best one at which we can arrive.

In this connection, special interest attaches to the study by one of us of the wall-rocks of the great ore-bodies at Mineville, during which thousands of feet of diamond drill cores were examined with the hand lens and in thin sections. The conclusion was reached that the rocks belonged in the syenite series now placed in the Algoman.\(^{83}\) In the later chapter on the iron ores we also note what has been earlier remarked by both American and Scandinavian observers—the association of these closely similar magnetites, both in America and in Scandinavia, with soda-rich granitic and syenitic wall rocks.

In spite of the somewhat indefinite and elusive nature of the evidence of relationships the ore-bearing formation is sufficiently distinctive and characteristic, both in the field and under the microscope, to permit us to distinguish it in the areal mapping and to designate it by a special symbol on the map.

In establishing the age relations of the normal, dark green syenite (quartz nordmarkite) to the older granitic rocks, there is far less difficulty. On the northern slopes of Fordway mountain, the Laurentian granite penetrates the Grenville sediments, producing a syn-

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\(^{82}\) Miller, W. J., Jour. Geol. v. 27, 1919, p. 29.

tectic rock. The syntectic in turn is found "floating" on the Algoman quartz-nordmarkite, which constitutes the major mass of the mountain. The quartz-nordmarkite also cuts the syntectic rock in the form of small stringers and pegmatitic offshoots.

THE KEWEENAWAN ROCKS

In commenting on our stratigraphic table in the early pages a paragraph has been given to the name "Keweenawan." We adopt this name of the Lake Superior geologists purely upon the lithologic similarity which our last Precambrian rocks possess with its most prominent members. Our rocks are limited to basaltic dikes, for the most part narrow. They are fresh, practically unmetamorphosed, and are believed to be older than the Potsdam sandstone of the upper Cambrian. We can not deny that they may be early Cambrian; but their wide extent in the Adirondacks leads us to correlate them with the Keweenawan.

Basaltic Dikes

Approximately one hundred twenty-five basaltic dikes, showing some variation in mineralogy and texture, have been discovered and mapped. They do not all appear as individuals on the map because at times several are so near together as not to be drawn separately on this scale. The dikes are the latest of the rocks in place, and are doubtless in largest number Precambrian. In the stratigraphical column the latter have been tentatively referred to the Keweenawan. A few, whose mineralogy allies them with the dikes of the Champlain valley, which cut the Utica shale, may be post-Ordovician. No statement more positive than this can be made, because all the wall-rock are Precambrian and from them no further evidence can be gained.

Regarding the age of the dikes and the growth of our knowledge with respect to them, it may not be without interest to make the following summary. In 1893 Kemp and Marsters,84 as the results of the two summers in the field and the compilation of all available earlier records, established the occurrence of two contrasted petrographic groups. The first group included the light-colored feldspathic dikes and small sills, specifically named bostonites; and the

second the dark, basic dikes embracing diabases, camptonites, monchiquites and fourchites. Geologically, the association of bostonites, camptonites, monchiquites and fourchites with nephelite-syenites in many parts of the world, was remarked (pages 21–22) and their connection with the nephelite-syenite and similar rocks just north of the international boundary at Montreal, was considered. Since the dikes in the Champlain valley, cut the latest Ordovician strata, the age of this group was established as later than the Ordovician. Almost all the dikes found in the Precambrian strata were diabases, but Kemp and Marsters drew no further conclusions about their age.

In 1894 C. H. Smyth, jr, described a series of diabase dikes near Gananoque, Ontario, in the Thousand islands, which, while cutting the Precambrian were themselves cut off by the overlying Potsdam sandstone and were therefore older than the upper Cambrian. In 1896, from observations of the dikes in Clinton county, which just enters the northern edge of the Ausable quadrangle, H. P. Cushing concluded that the diabase dikes were cut off by the overlying Potsdam and that there were therefore two epochs of outbreak, a Precambrian or at least pre-Potsdam, and a post-Ordovician. Professor Cushing remarked the great preponderance of diabases in the Precambrian areas. Of the three later varieties of basic dikes, only one case, a fourchite, had then been recorded in the old crystallines, although several syenitic dikes, related to bostonites had been described from Clinton and Franklin counties.

In the later paper in which the dikes at Rand hill are discussed, speaking of the diabase dikes, Professor Cushing remarks on page r62, as follows: “The Adirondack eruptives are very like those which characterized Keweenawan time in the upper lake region, and probably approach them as nearly in age as in character.” In the stratigraphical column given on an earlier page, we have tentatively placed the diabases in the Keweenawan. There remains, then, the presumption that if we find camptonites, monchiquites and fourchites in the Precambrian areas, they probably are outlying members of the post-Ordovician outbreaks. On this line of reasoning we have suggested the two ages of the dikes in our stratigraphic column.

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87 Cushing, H. P., Geology of Rand Hill and Vicinity, Clinton County, N. Y. State Mus. 53d Ann. Rep't v. 1, 1901, p. r39–r82.
In one case only does a dike show the effects of crushing from movement along the fault in which it is found. Presumably the dike was intruded in a fault and the crushing is due to renewal of movement. The dikes are very often in demonstrable faults. They are frequent in the iron mines of the eastern Adirondacks and almost always are associated with visible displacement of the orebody.

Some statistical summaries have been prepared to illustrate the size, strikes and petrographic characters. In connection with the matter of size the statement should be made that it is not always possible to measure the thickness, since instances not infrequently appear with only one side of the dike exposed. Fragments, moreover, can be found on the dumps at the now abandoned Arnold Mines, and B. T. Putnam records that several dikes cut and slightly fault the ore, but one can no longer go underground and see them. Eighty-six have been measured and recorded by the authors with the following statistical results.

<table>
<thead>
<tr>
<th>Size</th>
<th>Number</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1 foot</td>
<td>36</td>
<td>42.0</td>
</tr>
<tr>
<td>1 to 2 feet</td>
<td>18</td>
<td>21.0</td>
</tr>
<tr>
<td>2 to 3 feet</td>
<td>10</td>
<td>11.6</td>
</tr>
<tr>
<td>3 to 4 feet</td>
<td>7</td>
<td>8.1</td>
</tr>
<tr>
<td>4 to 5 feet</td>
<td>7</td>
<td>8.1</td>
</tr>
<tr>
<td>5 to 10 feet</td>
<td>4</td>
<td>4.7</td>
</tr>
<tr>
<td>10 to 15 feet</td>
<td>2</td>
<td>2.3</td>
</tr>
<tr>
<td>17 feet</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>22 feet</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>86</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

The commonest, therefore, are very narrow, nearly one-half being under 1 foot. Rarely do they exceed 10 feet. These relations make them generally very dense rocks from the chilling effect of the walls on the entering molten magma.

The irresistible effect upon an observer is a feeling of wonder that such narrow bodies of igneous rock were ever able to penetrate so far upward from what must have been the parent reservoir and still maintain their onward march despite the chilling effect of the walls. Nowhere in the Adirondack region have we ever found any representatives of this basaltic magma except in dikes.

The greater number of the dikes are found in the east and west strip at the northern border of the quadrangle. If we take such a strip 4 miles from north to south, it will contain about seventy of the known dikes, leaving only about fifty-five for all the rest of

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88 Tenth Census of the United States Reports, v. 15, 1886, p. 119.
the area. In this section we also find the most numerous local developments, in one case as many as eleven parallel ones were recorded within 100 feet across their strike.

In strike, far the greater number lie between northeast and east and west. Among eighty-three records, sixty-one are between these bearings. In statistics we have the following:

<table>
<thead>
<tr>
<th>Strike</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>N+S-N15E</td>
<td>5</td>
</tr>
<tr>
<td>N15E-N30E</td>
<td>1</td>
</tr>
<tr>
<td>N30E-N45E</td>
<td>7</td>
</tr>
<tr>
<td>N45E-N60E</td>
<td>16</td>
</tr>
<tr>
<td>N60E-N75E</td>
<td>20</td>
</tr>
<tr>
<td>N75E-N90E</td>
<td>25</td>
</tr>
<tr>
<td>N90E-S75E</td>
<td>5</td>
</tr>
<tr>
<td>S75E-S60E</td>
<td>2</td>
</tr>
<tr>
<td>S60E-S45E</td>
<td>0</td>
</tr>
<tr>
<td>S45E-S30E</td>
<td>1</td>
</tr>
<tr>
<td>S30E-S15E</td>
<td>1</td>
</tr>
<tr>
<td>S15E-S</td>
<td>0</td>
</tr>
</tbody>
</table>

In the directions between northeast and east and west and especially in the northern portion of the quadrangle there must be some marked structural lines of weakness, although they do not find very pronounced expression in the relief. In the Elizabethtown and Port Henry quadrangles with far fewer cases of dikes, the coincidence with the large structural lines has been remarked. Of thirty-two accurate records, nineteen fell between N35°E and N70°E, six were east and west, and four nearly north and south.

Still earlier, in Bulletin 95 of the New York State Museum, 1905, p. 278, H. P. Cushing remarked the general east and west trend of the dikes in the northern Adirondacks. The restricted locality in which they were believed by Professor Cushing to be most numerous is at Rand hill about 20 miles north of the Ausable quadrangle. Rand hill contains a strong complex of them, with a marked east and west strike. In Rand hill the dikes reach 40 to 50 feet in thickness.

Petrographic characters. Forty slides have been cut representing thirty-three dikes. Reserving comment on the naming of the rocks for a moment, they may be statistically grouped as follows. The statistics probably represent rather closely the numerical relations of the dikes in general, even if slides were prepared of only about one-quarter of the actual cases.

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabase</td>
<td>13</td>
</tr>
<tr>
<td>Olivine-diabase</td>
<td>7</td>
</tr>
<tr>
<td>Camptonite</td>
<td>7</td>
</tr>
<tr>
<td>Enstatite diabase</td>
<td>2</td>
</tr>
<tr>
<td>Monchiquite</td>
<td>2</td>
</tr>
</tbody>
</table>

Thus the three varieties of diabase together constitute 71 per cent of the total; the camptonites 22.6 per cent, and the monchiquites 6.4 per cent.

Diabase. By diabase we understand an igneous rock of a fine-grained to coarse-grained texture, with slight if any porphyritic development and consisting of labradorite, augite and magnetite. The texture is a marked and characteristic feature. The labradorite, or perhaps in minor amount, some closely related variety of plagioclase has crystallized in tabular crystals, relatively thin in one dimension in comparison with the other two. When broken or cut across, they give sections that are relatively long and narrow. Under the microscope the feldspars thus appear as an interlacing mass of so-called "lath-shaped" sections. The feldspars are relatively well-developed in crystal form and on the four sides of the tables, if not on the ends, have their own bounding faces. The spaces between them, which in section appear triangular or otherwise polygonal in shape, are chiefly filled with augite, whose shapes and boundaries are conditioned by the surrounding labradorite tables. Magnetite, almost if not quite invariably titaniferous, is also a space-filler between the labradorite crystals and is associated with the augite. The augite itself shows at times the violet hue which indicates the presence of titanium in its composition. Aside from these three minerals, other components are not abundant or of great importance. Apatite naturally does not fail, but presents small irregular bits, often associated with the magnetite. The magnetite is at times bordered by shreds of biotite which are generally esteemed by observers to be a reaction mineral, because of the mutual effect of magnetite and labradorite upon each other. While the extinction angles indicate that labradorite is by far the feldspar of chief importance, we may find now and then a stray andesine on the one hand or a bytownite on the other. The untwinned character of a rare feldspar section, the presence of potash in the few analyses which have been made of the diabases, and the secondary biotite give evidence of the presence of the orthoclase molecule, if not of actual and distinct orthoclase. In one dike a zonal orthoclase was identified.

Olivine diabase. From the above typical rock, the most important variation is the addition of olivine. With the increase in magnesia and iron oxide in the magma and the correlative decrease in silica, a composition is reached which admits of the crystallization of olivine, so that olivine-diabase results. The rocks are closely akin to the diabases proper and have only the new mineral as a distinguishing feature. Textures remain the same, and the olivine merely replaces some of the augite in the polygonal spaces between the feldspars.
Enstatite-diabase. In two dikes the augite has waned in amount to partial or entire failure and its place has been taken by a pale green pyroxene, with parallel extinctions and no visible pleochroism which we determine to be enstatite. No olivine is associated with it.

Textural varieties. The true and typical diabasic texture is subjected to at least two variations from the normal which are of much interest. In one dike the feldspar rods become greatly increased in amount and very long and slender. They exhibit starlike radiations from common centers which are striking and unusual. Nevertheless, the labradorites retain their strong automorphic boundaries as compared with the less abundant augites and the rock is to be considered as a diabase of variant textural character. In another case small laths of labradorite were concentrically arranged around an inner nucleus of some mineral, now altered to secondary carbonates either calcite or dolomite, and to quartz. A localized eye-like character was afforded.

Another variation from the typical texture is brought about by the tendency of the augite and olivine to assume their own crystal boundaries. One notes occasional eight-sided cross sections of augite and six-sided olivines, with a marked disposition to be larger than the usual run and to form a sort of phenocryst in the otherwise diabasic mass. Except the magnetite, all the components thus tend to have their own boundaries, or to be automorphic, a feature that is sometimes a marked characteristic of dikes the world over. This may go so far that the characteristic diabasic texture is fairly well obliterated. The great interest of the diabases in their petrographic relations, lies in the fact, that in the order of crystallization the feldspars completed their period of formation before the ferro-magnesian silicates. The latter thus had to adapt themselves to the spaces left between the already formed labradorite tables and were forced to assume such shapes as the interlacing tables impressed upon them. In the general run of igneous rocks just the reverse holds true; that is, the ferro-magnesian minerals usually complete their growth before the feldspars and are automorphic as against the latter. There is a widespread tendency on the part of the diabase dikes to revert to this “normal” order of formation and to depart from the strict diabasic texture. Nevertheless, we prefer to establish the characteristic diabase as the type and to trace the variations as aberrant. We thus use the name “diabase” as the general group name, admitting that among the dikes there is some range. A single dike, moreover, shows in its
own cross section notable variation. Next to the walls it is chilled for an inch or two to a dense opaque black or dark brown glass, with such abundant sprinkling of magnetite or at least ferrite dust through it as to appear opaque even in very thin section. In the glass are set phenocrysts of labradorite, augite and at times olivine, with good boundaries; as one recedes an inch or, in the thicker dikes, a few inches from the edge, the normal diabasic textures assert themselves. Plates 4 and 5 exhibit a series of eight photomicrographs of thin sections taken at measured intervals across a 10-foot dike. The dense, chilled texture on the contacts passes into coarse textures at the center.

**Alteration.** Many of the dikes, although appearing fresh and black in the hand specimen are found under the microscope to be greatly altered. Calcite or some related carbonate accompanied by considerable quartz has richly resulted from both plagioclase and augite. Chlorite has taken the place of the augite and spread all through the rock, staining it green or yellow as viewed under the microscope. Olivine has locally passed into serpentine, probably soon after crystallization and while the rock was still highly heated. The calcite, quartz and chlorite no doubt more largely represent the changes from weathering.

In the large dike at Palmer hill, and as noted by one of us in 1893, the feldspar has changed to scapolite. While we have not observed this change in other dikes, the early observation has again been verified. In accordance with the modern viewpoint, we would refer this change to the rather highly heated stage, following consolidation and to the influence of the emissions of the magma usually described as mineralizers.

**Post-Ordovician Dikes**

**Camptonites.** The name "Camptonite" is derived from the township of Campton, in the Pemigewasset valley of New Hampshire, where at Livermore Falls there are five rather famous dikes, originally described by George W. Hawes, as diabase, diorite, syenite and olivine diabase. Seven years later H. Rosenbusch established upon these the group of dike rocks which he called "camptonites"

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Plate 4 with plate 5 exhibits a series of eight photomicrographs from thin sections taken at the stated intervals, across a 10-foot diabase dike, three-quarters of a mile north of Ausable Forks. In each picture the vertical diameter is 3 mm or one-eighth inch. The series is designed to illustrate the increasing coarseness of grain, from the chilled contact to the center, decreasing then to the opposite contact. No. 1, chilled and dense, south contact of diabase against granite. Phenocrysts of labradorite in rude flow lines. No. 2, 6 mm or one-quarter inch from no. 1; increasing coarseness of groundmass and of phenocrysts. An olivine crystal in the upper, middle field. No. 3, 30 cm or 1 foot from the contact; marked increase in coarseness of grain. The porphyritic character has almost disappeared. No. 4, 1.65 m or 5 feet from contact; middle of dike; coarsest grain. Series continued in plate 5. J. F. Kemp, 1919.
Plate 5 continues plate 4. No. 5, 7.5 cm or 2.5 feet from north contact; practically the same as no. 4. No. 6, 30 cm or 1 foot from north contact; grain practically as coarse as no. 4. No. 7, 25 mm or 1 inch from north contact; visibly coarser than no. 4. No. 8, north contact with granite; labradorite phenocrysts in flow lines, but visibly larger than those of no. 1. J. F. Kemp, 1909.
Wave cut terrace on eastern slope of hill mile west of North Jay.
Photograph by H. L. Alling in 1915.
despite their mineralogical varieties. His description when translated read:  

Microscopically the rocks are in part quite compact, black to blackish-gray and of almost basaltic habit; in part they are of porphyritic texture because of phenocrysts of basaltic hornblende; less often of plagioclase or of analcite. The iron-bearing components strongly predominate; the feldspars recede; and carbonatization is generally developed. Microscopic study reveals a groundmass, essentially composed of small rods of plagioclase and brown amphibole. Quite generally, but always sparingly, biotite is associated. Green augite usually in an advanced stage of alteration to chlorite is generally and richly present, together with apatite needles and ilmenite crystals. Between the tiny plagioclase rods appear here and there thin pellicles of glassy basis. We are not surprised to find, therefore, an occasional amygdale filled with calcite and delessite. The most frequent phenocrysts are large, and often zonal, basaltic hornblendes. In similar relations but only seldom, we find slightly altered olivines and light brownish violet augites with the habit of basaltic augite and with the hourglass nucleal growth. The augite-phenocrysts are almost always surrounded by amphibole flakes and rods. Rarely the augite phenocrysts increase so greatly in amount as to displace the large hornblendes even completely. These are the rocks which Hawes called in part diabase and olivine-diabase. The typical feature of porphyritic structure is brought out in these rocks in the repetition and the richness of the amphibole and pyroxene growths and in the quite regular failure of the feldspars to appear among the products of the older generation.

Thus to be a true camptonite in the sense of Rosenbusch, we should find basaltic hornblende as small rods of the later generation and as phenocrysts of the older, when not displaced by augite in the latter relation. The dikes listed as camptonites have, in all cases but one, the brown basaltic rods as a conspicuous feature. They are from 2 to 3 times as long as broad, and vary in actual dimensions with the width of the dike. Since the camptonite dikes are generally less than a foot in width, the rods are small, running .1 mm across by .2 to .3 mm long. They are of a rich chestnut brown and are a beautiful mineral under the microscope. The six-sided cross sections are developed in great perfection. The extinction angle is very low, and the pleochroism brown to yellow is pronounced. No large phenocrysts of the brown hornblende have been found in the eight or ten slides examined. With the hornblende

93 Rosenbusch, H., Mikroskopische Physiographie der Massigen Gesteine, 1886, p. 333-34.
94 Meaning as he, Rosenbusch, defined porphyritic structure.
are associated eight-sided rods of pale green augite, of very much the same general size as the hornblende. There are, however, occasional larger phenocrysts of augite. Olivine is almost invariably present as relatively large phenocrysts, .5 to 1 mm. Alteration is customarily advanced and may leave only a mass of carbonates and streaks of iron oxide. The shape of the mass, however, indicates the original olivine. Labradorite rods are universal in the camptonites but in relative amount to the ferro-magnesian minerals, vary between fairly wide limits. Alteration has often greatly affected them. Magnetite is universally present, and in some dense specimens assumes fernlike growths. Alteration of the rocks to carbonates is widespread and produces local areas wherein little else is to be seen. One case of amygdules has been observed.

Monchiquite. One or two narrow dikes have revealed under the microscope little else than a mass of minute rods of augite, sometimes of a double forked or clothes-pin outline, sometimes in stellate radiations. Between the rods an isotropic or feebly refracting, colorless matrix may be identified. Set in the mass are sparingly distributed phenocrysts of both olivine and augite. A sprinkling of bits of magnetite make up the slide. The rock thus corresponds to monchiquite, a variety of dikes named by Hunter and Rosenbusch from the Monchique mountains of southern Portugal. The monchiquites were believed to have olivine, with augite, hornblende and biotite (any one or several of the last three) in a glassy groundmass. The “glassy” groundmass was later shown by L. V. Pirsson to be analcite. Monchiquites have been described from the Champlain valley, but additional interest attaches to their appearance back in the Precambrian areas.

FAULTS

In Adirondack geology faults are of at least two degrees of magnitude and of some demonstrable succession in time. There are the relatively small dislocations which are brought out by displacements of magnetic iron ore-bodies, very often with a basaltic dike in the resulting fissure, and which are revealed with all desirable accuracy in the mine workings. The displacement is a few

97 For example, writing of the Arnold mines in 1880 when they were active, B. T. Putnam states, “The veins of ore are cut by several dikes and often slightly faulted.” Tenth Census, v. XV, p. 119.
feet as a rule, and the faults are of the normal type; that is, where inclined, the hanging wall of the fault has slipped downward on the footwall. The basaltic dikes in the faults show little or no signs of crushing and entered unquestionably at a time subsequent to the faulting movement. These faults, therefore, may be considered early or pre-Keweenawan. There are other small faults which displace the dikes themselves and are subsequent to their entrance. Figure 9 illustrates an instance of this kind and is sketched from a dike in the extreme northeastern corner of the quadrangle. Similar cases have been observed and illustrated from the Elizabethtown quadrangle, which lies just south of the Ausable.98 There are thus at least two series of small faults; one antedating the diabasic dikes and the other later than their entrance and consolidation.

In contrast with the small faults are the large ones which are revealed by the blocky nature of the topography; by the crushed zones appearing beneath cascades along the brooks which have searched out these lines of weakness in developing the courses of drainage; and by the sharp linear contacts of contrasted members of the local geology. A geological map of a quadrangle in the eastern

98 Sketches will be found in Geology of the Elizabethtown and Port Henry Quadrangles. N. Y. State Mus. Bul. 138, 1910, p. 58, 77 and 78.
Adirondacks almost invariably reveals patterns of color which can be explained only in this way. Faults are also indicated by steep and precipitous cliffs, whose rocks have been given a sheeted structure by the fault movement, and which have been brought out in recently accentuated relief by the plucking action of the continental ice sheet. In the Elizabethtown quadrangle to the south and in the Mount Marcy quadrangle to the southwest, the faults running with impressive regularity to the northeast and northwest have broken the surface into a series of mountainous blocks of extraordinary uniformity. Their geometrical distribution has been followed by the so-called trellised drainage.99

The northeast and southwest systems are not developed with such regularity in the Ausable quadrangle, although, as the map brings out, we have several which follow these directions. The most impressive is a northeast fault which passes through the "Gulf," a steep-sided valley, whose bottom is 1200 feet below the summits on either side of it. The Gulf is an extremely striking topographic feature and has played an interesting part in the glacial and post-glacial geological history. Its fault is believed to be later than the slightly northwest series of three, which are offset by it on the north side somewhat to the west. In the eastern central part of the quadrangle, a fault running a little east of north is offset in the reverse direction by a later northwest one. From these cases it would appear as if the northeast faults were older than the northwest ones.

The possible ages of these faults can not be sharply identified in the absence of later fossiliferous strata. Professor Cushing has described a series of faults in Chazy township on Lake Champlain,100 25 miles northeast of the area here described. They displace Ordovician strata and one naturally associates them with the epoch of mountain making now usually named the Taconic, which followed after the Ordovician period and presumably initiated the upheaval of the Green mountains. In New York State Museum Bulletin 225–26 on the West Point Quadrangle, Professor Charles P. Berkey

Cushing, H. P., Faults of Chazy Township, Clinton County, N. Y. Geol. Soc. Amer. Bul. 6, 1895, p. 285–96. On the map, plate 12, the northwest faults and the nearly east and west ones, appear to be cut off by the northeast and north and south ones. This relation in time is the reverse of the one noted in the Ausable quadrangle. It is only fair to say that in flat and easily discriminated Paleozoic strata, faults can be more sharply traced and mapped than in the old crystallines.
has identified in the Hudson valley both Taconic faulting and folding, and another set that followed close on the deposition of Triassic sediments. We can only speculate as to whether the post-Triassic faulting also affected the Adirondack area, in that it is very severe in the lower Hudson valley.

GLACIAL GEOLOGY

Multiple Glaciation

The Adirondacks undoubtedly have been subjected to repeated invasions of continental ice bodies but the number of times the area has been so buried is not known. The invasion may have begun in the Precambrian. Coleman and others report Precambrian glacial deposits from various sections of Canada where the tillites are presumably of Lower Huronian age. As a consequence we have kept our minds prepared for similar deposits in the Adirondacks, but no ancient rocks have been found which could be interpreted as conglomerates or tillites. While we have no evidence for believing that lower Huronian glaciation reached these mountains, there is some evidence for believing that glacial action has taken place which antedated the last continental ice body.

In the stream valleys where the thickness of the glacial débris is unusually great a difference in the degree of weathering can be detected between the lower and upper layers; but we realize that more satisfactory evidence for multiple glaciation is obtainable in the Finger lakes district of the State, on Long Island and in New Jersey than has been secured in the mountainous regions.

In as much as the majority of the moraines, deltas, striae and glacial lake features are clearly to be assigned to the last invasion, all previous continental ice bodies are commonly ignored in seeking the origin of many physiographic features, yet the rounded contours of the mountains and the U-shaped character of many of the valleys may well be the result of the combined erosion of several ice bodies.

Thickness and Movement of the Ice

In attempting to solve the question, how thick was the last ice sheet over the Adirondacks at its fullest extent, we must consider, first, that it passed beyond Manhattan island so that it is necessary to postulate a slope involving sufficient pressure to drive it to this fairly remote point; second, that there is a difference of opinion.

whether the highest peaks were glaciated by the continental body or not; and third, if a great thickness over this area is suggested, whether the ice could remain as such under the enormous load. Would it not melt in the bottom portion in spite of low temperatures?

No matter what theory we may entertain regarding the motion of glaciers, some great force was necessary to carry the continental ice to southern New York. Leverett and Taylor\textsuperscript{102} believe that the ice in the middle states had a greater slope than 18 feet a mile. If we assume 25 feet, we calculate, starting at zero at New York City, 6500 feet of ice on the Ausable sheet. This would cover the mountains of the Adirondacks. Fairchild\textsuperscript{103} says: “At its maximum the ice covered the highest points in the State, the Adirondacks (5344 feet) and the Catskills (4205 feet) mountains . . . . Shackleton found that the great outlet glacier in Antarctica, named the Beardmore, had a rise of 60 feet per mile for 100 miles, with declining rate inland . . . . or 40 feet for the entire distance (275 miles) . . . . If we assume 40 feet per mile on the Hudson-Champlain meridian it gives 12,500 feet of ice on the Canadian boundary” or 10,400 feet over the Ausable quadrangle. Coleman on the other hand has recently stated\textsuperscript{104} after a trip to the top of Mount McIntyre that he does not believe the ice covered the highest mountains of the region.

The question whether such thicknesses as are here suggested could actually exist due to the great pressure upon the basal layers, has been raised by some students of glacial geology. Pressures up to 2000 kilograms a square centimeter lower the freezing point of water. Many have assumed that the same result continued for even greater pressures. The contrary, however, has been shown\textsuperscript{105} to be the case. Beyond the pressure of 2000 kilograms a square centimeter, the freezing point is raised (through several inversion points) until at 20,000 kilograms a square centimeter water freezes at about 60 degrees above zero centigrade.

Whether the glacier completely overrode the mountains or not, we do believe that with the return of warmer temperatures the summits were first relieved of their load and became nunataks, perhaps supporting local glaciers. Continued melting lowered the line of

\textsuperscript{103} Fairchild, H. L., Bul. Geol. Soc. Amer., v. 24, 1913, p. 135. 
\textsuperscript{105} Tammann, Annalen der Physik, 1899 (3) 68.664; 1900 (4) 2, 1, 424; Zeit. f. Phys. Chem. 1910, 72, 609, 1913, 84. 257; Bridgman, Zeit. Anorgan Chem. 1912, 77-377.
contact of the ice with these peaks in slowly descending and ever widening rings. Eventually these rings joined with each other until the main Adirondack highland was surrounded by an ice ring that effectively isolated the area from the rest of the State. It is felt that this condition has a bearing upon the flora and the type of soil now prevailing.\footnote{Alling, H. L., N. Y. State Mus. Bul. 207–8, p. 137; N. Y. State Mus. Bul. 211–12, p. 93.}

Numerous glacial striae or scratches are found upon ledges recently exposed, chiefly through road construction. Most of the forty-two striae recorded and shown upon the map were discovered beside the highways in the valleys. The striae indicate the direction taken by the waning ice lobes and not the direction of flow of ice when at its maximum. The effect of the topography upon the ice movement is well indicated by careful study of the striae. A few (which may be in error due to local magnetic attraction) show a direction due south or slightly east of south, the majority, however, are from 40 to 60 degrees west of south.

**Moraines**

Glacial débris in the form of true moraines was far more common during the withdrawal of the ice than that which exists today, because following their deposition the valleys were flooded with a large number of glacial lakes whose wave action and currents destroyed and reworked them into lake deposits. Those that are still preserved show that the ice which deposited them was retreating at the time. Crescent-shaped moraines are situated in many of the valleys. One of these can be seen south of Lewis on the southern edge of the sheet where the moraine is being bisected by Turpee brook. The lateral prongs of this moraine extend northward for half a mile on each side of the valley. Similar ones are situated in the valley of the Smith graphite property,\footnote{Alling, H. L., N. Y. State Mus. Bul. 199, 1918, p. 113.} near Trout pond, in the Styles brook valley and in the pass of Sprucemill brook.

The ice lobes in moving through narrow fault-line valleys, especially those with a northeast and southwest trend, frequently blocked them at both ends by crescent-shaped moraines. A considerable number of the lakes and ponds of the Adirondacks fill basins formed in this manner. Trout pond is an example, but more typical illustrations are the Cascade and Ausable lakes in the Mount Marcy quadrangle and Silver and Taylor lakes in the Lake Placid sheet.
Eskers

Eskers have been noted in several of the valleys; one is located close to the west side of the highway running from Clintonville to Trout pond. It is 3 3/4 miles south of the first named locality. It can be traced for nearly half a mile and varies from only a few feet to 50 feet in height. It has a general southern trend, but locally departs from a straight course in its wanderings up and down over previously deposited till. The southern end flattens out into an esker-fan delta. This delta was deposited in one of the glacial lakes here described.

Another esker is to be noted in the valley of the Sprucemill brook extending in an east and west direction, a direction at variance with that taken by the waning ice-lobes. We conclude that this was deposited by a local glacier flowing eastward from either Hurricane or Saddleback mountain. In the belief that local glaciers, chiefly confined to the higher peaks of the Adirondacks, followed the withdrawal of the continental ice, we are in accord with Taylor,\textsuperscript{108} and Ogilvie.\textsuperscript{109} More recently D. W. Johnson\textsuperscript{110} has added his own testimony to the published results of those who have preceded him. Clear pond, near the center of the quadrangle, is dammed by a little esker. Whether it is of local or of continental origin has not been determined.

True kames have not been seen in the area. It is, of course, possible that they were deposited, but the general flooding of the valleys by the subsequent glacial lakes probably has so modified their appearance as to render them unrecognizable.

Terraces

Introduction. The flat-topped terraces, sandy plains, gravelly levels and dissected deltas that flank the valleys of the Ausable and adjacent sheets can not fail to impress an observer. These levels furnish the sites of many farms, houses and hotels. Since the middle of the last century they have been recognized as stream deposited glacial drift laid down in bodies of standing water. Even before the present day of good roads and rapid transportation many were observed to extend along the valleys for miles at nearly horizontal levels, separated from one another by uniform differences in elevation.

\textsuperscript{108} Taylor, F. B., Amer. Geol., v. 19, 1897, p. 395.
\textsuperscript{109} Ogilvie, I. H., Jour. Geol. v. 10, 1902, p. 397-410.
In 1848 Kellogg noted the almost diagrammatic terraces and deltas at Elizabethtown, which were later and independently described by Ries. Warren Upham in 1891 suggested that the Hudson-Champlain valley held a lake dammed by ice-lobes. Baldwin in 1894 and Wright 4 years later contributed papers dealing indirectly with these terraces. Taylor in 1897 was the first to describe terraces and lake bottoms in the interior of the mountains and to conclude that their origin was due to flooding behind glacial ice dams. Kemp, in the following year noted two or three sets of terraces in Keene Valley. Cushing, working in the Saranac region, discusses the origin of sand plains and terraces situated there, ranging in elevation from 1450 to 1660 feet. He says: "These sands were probably deposited as deltas in a large and irregular, shallow lake formed back of the ice tongue . . . during its slow retreat north."

Ogilvie 2 years later dealt especially with the erosional history of the Adirondacks but was perhaps first to appreciate that the correlation of the different terraces in the interior among themselves and with those in the Champlain valley presented important possibilities but was difficult of accomplishment.

Peet and Woodworth further added to our knowledge of the terraces along the eastern margin of the mountains, only incidentally referring to the shoreline features in the Ausable quadrangle.

In the bulletin on the Elizabethtown-Port Henry quadrangles, Kemp briefly noted the Elizabethtown levels and stated that the 540-60 terraces extended north into the southeastern portion of the Ausable quadrangle, where beautiful terraces were developed. Be-

114 Baldwin, Pleistocene History of the Champlain Valley. Amer. Geol., v. 13, 1894, p. 170-84.
115 Wright, Glacial Phenomena Between Lake Champlain, Lake George, and the Hudson River. Amer. Geol. v. 22, 1898, p. 333-34.
118 Cushing, H. P., N. Y. State Mus. Ann. Rep't of Director, 1900.
119 Ogilvie, I. H., Jour. Geol., v. 10, 1902, p. 397-412.
ginnin in 1905, Fairchild has written extensively on the glacial lakes of the State, discussing the terraces, deltas and marine submergence of the Champlain, St Lawrence and Hudson valleys. Alling in 1916 outlined the history of twenty-four distinct lakes within the east central Adirondacks, some of which occupied some portion of the Ausable quadrangle. Further discussion of these lakes has subsequently appeared.

**Origin and correlation of terraces.** It was realized that there were two distinct classes of terraces within this section of the Adirondacks; the terraces, deltas and beaches along Lake Champlain and those to the west, in the interior of the Mountains. While both classes undoubtedly owe their origin to the presence of the ice, they present problems peculiar to themselves. Complete and satisfactory correlation between the two sets is rendered difficult because each class has been studied by a different group of geologists. The attempt, however, has been made to reconstruct the geography of glacial lake (Pleistocene-Champlain) times by making use of the recorded data supplemented by our observations.

It was realized that any satisfactory progress could only be made by ascertaining the exact elevation of the various terraces. This was undertaken by refined aneroid observations.

**Differential uplift.** Tabulation of the elevations of the terraces and beaches showed that individual terraces of the same series varied in altitude, those to the north possessing a slightly higher elevation than those to the south. The method of Woodworth of plotting the terraces on a profile, demonstrated that such was the case. In other words, the land has been deformed by warping northward since the lakes existed. This was in harmony with the

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126 A standard surveying aneroid barometer, carefully checked against established bench marks was employed. Readings were corrected for the temperature of the air; a thermometer was taken into the field. The variations due to weather conditions were noted with a standardized barograph and were further modified by comparisons with previously drawn curves showing diurnal variations in atmospheric pressure and the lag of the two instruments. Field methods were developed quite similar to those described by Frederic Lahee in Economic Geology, volume 15, 1920, pages 150–60.

observations made in the Champlain valley. The isobases of Fairchild were employed in projecting these to a uniform basis for comparison. When this was done it was seen that each individual set possessed its own value of warp per mile. The lakes that existed during the early stages of the withdrawal of the ice had a higher value. For example, the lake here called Upper Newman (1800–25 feet elevation at present time) has a tilt of 3.52 feet a mile, while the Wilmington lake of later age (1100–50 feet) has a warp of only 2.94 feet a mile. These results can be explained in either of three ways: (1) During the early stages of the series the mass of ice tongues in the valleys was greater than it was at a later stand when the later lakes occupied the vacated valleys. Thus the gravitational attraction of the ice in deforming the surface of lakes as suggested by Leverett and Taylor and as applied to the older Maumee beaches might be the cause of the variations in these figures. (2) The isobases used are those proposed by Fairchild for the amount of uplift since Lake Vermont (Marine level) waters occupied the Champlain valley. It does not necessarily follow that the lines of equal uplift during the stages obtaining before that body of water came into existence made identical angles (20° from the latitude parallels) with the latitude lines. It is possible that each distinct lake stage possessed its particular set of isobases. If this should prove to be correct then the figures for each lake level are less significant. (3) The third explanation is that the differential land uplift had begun before or during the early stages of these lakes and continued through the time of the later stages and consequently Fairchild’s figures represent only part of the total uplift. Inasmuch as warping and uplift are considered to be functions of each other it would follow, assuming this hypothesis to be correct, that the total uplift would be greater than that formerly maintained by Fairchild. Other observers of the raised New England shore line believe, however, that Fairchild’s figures are excessive. If De Geer’s isobases are extended from the New England coast

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to the Champlain-Adirondack region different results would follow from our observed figures. Consequently all that our figures definitely prove is that there has been a warping of the surface of the land since late Pleistocene-Champlain times.

As the majority of the terraces found in the east central Adirondacks were deposited in local lakes of limited extent, their history can be deciphered without field observations outside of the adjacent quadrangles. When, however, we descend from the high lake levels to those at lower elevation we encounter more extensive lakes, finally reaching those of the Champlain-Hudson valleys. The diagrammatic levels of Elizabethtown, which extend northward into the southeast corner of the Ausable quadrangle, and those in the vicinity of Clintonville and Ausable Forks are those of the "Marine level" of Fairchild or of "Lake Vermont" of Woodworth. We can not discuss in detail whether these terraces were deposited in estuaries of sea-level waters or in a fresh water lake.

The subject of Pleistocene marine submergence due to ice loading has been studied in the light of isostasy.\textsuperscript{133} Daly says: "Many lines of evidence seem to support Jamieson's suggestion that the earth's crust has been plastically deformed by glacial loading; and, in the reverse way, by unloading through the melting of the ice-caps." If the land surface was depressed below its former level by the continental ice, the theory of isostasy suggests that, as a consequence, a rise of land beyond the margin of the glacier would be expected. Thus there may have been a bulge south of the reach of the glacier in response to the stress exerted by the ice load. Negative isobases should be drawn south of the zero isobase on the maps showing Pleistocene submergence. As the ice withdrew from the area, it is reasonable to expect that this bulge would migrate northward following up the retreating ice. Such a bulge would act as a barrier to the south, preventing open connection with the sea. Woodworth\textsuperscript{134} and Stoller\textsuperscript{135} thus regard the body of water in which the Elizabethtown and Ausable Forks deltas were deposited as a lake, called Lake Vermont.

**Stream terraces.** Many of the terraces that flank the valley walls are in close proximity to rivers. In the majority of individual cases it can not be decided whether they are lake deposits on the one hand,

\textsuperscript{134} Woodworth, J. B., N. Y. State Mus. Bul. 84.
\textsuperscript{135} Stoller, J. H., Topographic Features of the Hudson and the Question of Pleistocene Marine Waters in the Hudson-Champlain Valley. N. Y. State Mus. Bul. 183.
or stream terraces and meander cusps on the other. The similarity of these two different kinds of terraces with each other has been pointed out before.\textsuperscript{136} In a few instances it can be seen by the crescent shaped form of the cusp that the river was the agent. These terraces, however, are individually unique in their elevations and fail to correlate with others situated to the north or south in the same valley. Where levels of disputed origin extend a sufficient distance along a north and south valley so that a difference in elevation of the two extremities can be measured, it is possible to determine their origin. The main drainage of this section of the Adirondacks flows northward and consequently the northern end of a stream terrace is lower than the southern end. But as the post-glacial readjustment was a warping to the northward it follows that a terrace of glacial lake origin would slope in the opposite direction. It is our belief that, given a small ill-defined terrace along a river, without knowing the elevation of adjacent terraces it would be almost impossible to classify it. It is possible to discriminate between stream terraces and those of glacial origin by measuring the elevation of all levels found and by plotting them in profile. Those which fail to harmonize with those of undoubted glacial origin are tentatively regarded as stream terraces. The measuring of additional terraces, the rechecking of those previously noted has resulted in constant regrouping. We feel that this refining process is likely to continue and even today we have recorded some thirty-five levels whose origin is uncertain while 63 others are at present cataloged as stream terraces. In spite of this uncertainty we believe that the main story of most of the glacial lakes that occupied areas within the Ausable and adjacent quadrangles can be told.

Beaches

In addition to the terraces and deltas left by the glacial lakes there are well-preserved beaches situated on the sandy covered slopes of some of the hills. These are shown today as nearly horizontal niches or narrow benches more easily seen and recognized from a distance than when one is standing upon them. These beaches can readily be overlooked as they are often obscured by forest growth. Almost as many have been found by the use of the aneroid as by observation from the highways or in making a traverse up the valley sides. After the general elevation of a given lake had been recognized from

previously noted terraces, deltas or beaches, additional ones of the same lake were more readily found.

There are two groups of beaches within the Ausable quadrangle. On the slopes of the hills between Lower Jay and North Jay there are several beaches whose character seems certain. They range from 857 to 1059 feet, in altitude. Plate 6 shows two beaches, one at 880 and the other at 917 feet. They are best shown on the east side of the hills, while the Ausable river is a mile to the west of them. In as much as they correlate with other terraces there seems to be no escape from the conclusion that they are lake beaches and not stream terraces.

The other group is even more impressive. It is located to the west northwest of Lewis in the Sprucemill brook valley. The series range from 922 to 1343.5 feet while terraces extend to the 1650 foot contour. Some of them harmonize with extensive lake levels while others seem to have been formed by marginal drainage along the margin of the ice lobes. Plate 7 gives the appearance of the beaches in this series.

Wave cut cliffs add their evidence for the existence of glacial lakes in the quadrangle. In the “North Jay” group a wave cut terrace in a lateral moraine is easily seen from the highway.

**Glacial River Channels**

The recognition of glacial river channels, many of which are now dry, within the quadrangle has thrown much light upon the origin and history of the terraces found in the east central Adirondacks. These channels represent the courses followed by the rivers draining the lake flooded areas. The areas for 2 or 3 miles on both sides of the township line between Jay and Chesterfield are traversed by these channels and furnish an attractive field in which this phase of glacial geology may be studied. In fact, there is a belt in the central portion of the quadrangle extending from Ausable Forks and Clintonville south across the southern boundary of the sheet to Elizabethtown that can be referred to as the “channel belt.” The lakes that existed in both branches of the Ausable river found escape through the narrow fault-line valleys extending across the range of mountains consisting of Jay, Bluff and Black.

The fault-line valley of the Gulf (see map) and the locality called “South Gulf,” which extends south from the west end of the former, are perhaps the most striking courses followed by glacial rivers. The “South Gulf” channel is the longest so far traced in
this section of the Adirondacks. It extends from a mile south of Ellis mountain, to the west of Black, through Coonrod brook, Kelly brook, Hale brook, and the swamp that encircles the western slopes of Mount Fay. Various branches lead off from it to the east and represent successive outlets opened by the retreating ice lobe lying in the valley of the north branch of the Bouquet river. The river that flowed eastward through the Gulf turned southward when it reached the eastern end of the valley where it encountered the ice lobe. From that point southward it flowed between the ice and the sides of the hills, the ice forming one bank of the river. As the ice tongue melted, the river changed its course by flowing at a lower elevation, farther down the slope. These one-bank channels are today wide horizontal grooves cut into Grenville strata, plainly discernible even when the rock is quartzite.

The physiography of the southern face of Ragged mountain presents rather puzzling features which were better understood when it was found that glacial rivers have their courses here. Other channels have been noted that play an important rôle in reconstructing the geography of the late Pleistocene (or Champlain epoch of some writers).

**Contract Plunge Basins**

The Ausable quadrangle is perhaps unique among Adirondack topographic sheets in that within its boundaries there are at least seven Pleistocene cataract plunge basins, some of which are now filled with ponds. They are situated in the glacial river channels. During the late stages of the lakes in the Ausable river valley the drainage was eastward and it was at this time that these cataract plunge basins were formed. The most impressive and beautiful of all is Copperas pond. This is situated in the town of Chesterfield within the Hale Brook Park. Copperas pond is a small oval shaped body of water lying in a deep rock bound basin surrounded by a fine growth of white and red pines. Its present outlet consists of a trickle of water flowing over a broad, water worn spillway which is obviously the result of erosion of a much larger river. The basin in which this little gem now lies was hollowed out by the cascading waters of a glacial river as it plunged over a ledge of the ore formation granite. In plate 10 Copperas pond is shown from the southeast bank, looking upstream. The cliff over which the water plunged is located in the trees in the background.

137 Unfortunately there are several lakes of this name in the Adirondacks. Note one in the Lake Placid quadrangle in the Wilmington Notch.

138 A private game reserve.

The Keene lake occupied Keene valley at a present altitude of 2100 feet and is shown touching the southwest corner of the quadrangle. It drained south. A part of an early stage of Upper Newman lake is indicated on the left margin of the map. The Elizabethtown-Lewis valley was filled with ice at this stage.
Plate 7

One bank glacial channel on the southeast slopes of Black mountain, Ausable quadrangle. Outlet channel of St Hubert's lake. Photographs by H. L. Alling in 1915.
Plate 8

Boulder moraine near Cross. Evidence of glacial stream action along the margin of the ice lobe lying in the Trout pond-Cross valley. Photograph by H. L. Alling in 1915.

Plate 9

Glacial boulder delta, near Copperas pond. Looking north. Altitude 705 feet. Photograph by H. L. Alling in 1915.
Figure 11 Glacial lake succession in the Ausable quadrangle. Stage 2. The retreat of ice opened up the Wilmington notch, allowing an early stage of Upper Newman to drain westward. Altitude at present time, 1740–80 feet.
Nesbitt pond, close by, is another plunge basin lake formed at an earlier stage. Other and almost as impressive lake basins of the same origin are situated to the northwest of Copperas pond in the same river channel in which it lies, although the topography fails to indicate them, and in some instances is decidedly in error. Careful study of the map will reveal two blue dots about .6 of a mile north of Round lake where the 1000-foot contour makes a sharp turn. These represent Pleistocene pot holes formed in this channel.

In the fault-line valley of the Gulf, is another basin of similar character. Instead of retaining a lake the basin is today nearly filled with swamp growth. These cataract plunge basins are just as instructive and characteristic as the more familiar lakes southeast of Syracuse.\(^{139}\)

The height of these Pleistocene falls in the Ausable quadrangle was inferior to those just mentioned from central New York. Copperas pond and the Gulf falls had a drop of 50 feet as contrasted with Jamesville's 169 feet. This can be explained by noting the difference between the rocks and the way they have weathered. One is granite; the other is limestone.

There are two small cataracts near the southern border of the quadrangle south of Mount Fay. They are crudely indicated by curious little twists drawn in the 1400-foot contour by the topographer.

In examining the topographic map for plunge basins the reader would reach the conclusion that Orebed pond, a mile and a quarter west of "Cross" was another, with a second one-half a mile north. Unfortunately, however, the contouring is defective and has failed to convey the actual field observations. It is believed that the basins are due to cascades, rather than to falls.

**Glacial Lakes**

In this bulletin we are applying the term "glacial lake" only to those bodies of water which owed their existence directly to the ice itself. All lakes which lie in basins formed by morainal deposits are referred to as "morainal lakes"; other lakes of allied origin as "cirque lakes" and "kettle hole lakes." Consequently, if we use this nomenclature, there are today no glacial lakes in the Adirondacks. The lakes here described and mapped are extinct.

There were two series of glacial lakes in the Ausable quadrangle.

Plate 10


Plate 11

Delta level of Lake Vermont (marine level). South bank of Ausable river near Clintonville. Photograph by H. L. Alling in 1916.
Figure 12 Glacial lake succession in the Ausable quadrangle. Stage 3. A late stage of Lower Newman lake (1700–40 feet) is shown here. Ice in the Elizabethtown-Lewis valley had retreated to allow the Rhododendron lake at 1650–1700 feet to form.
One set occupied the valley of the east branch of the Ausable river, and the other set occupied the valley to the east, in Elizabethtown and Lewis. The mountainous massif of Ellis, Bald, Black, Bluff, Jay, Saddleback and Hurricane mountains separated these two groups. The two sets did not share a common history until Lake Vermont brought about a union of the two areas, when the water at the northern end of this range was unblocked by the retreating ice.

We have found that the nature of the shore line features of the lakes which existed at the high elevations from 2200 feet down to 1300 feet are less definite than those at lower elevation. The early lakes do not seem to have maintained a constant position or level for any great length of time. This may be explained by regarding the spillways as controlled by ice rather than by ledges of bed rock. The retreat of the ice was not a uniform withdrawal in all probability. The rate must have been variable, the lobes stopping and even readvancing only to reassume a retrogression. While we are fully aware of such possibilities, it has not been feasible to take it into consideration in establishing the geography of this period. Considerable work must be undertaken before this factor can be introduced into the history of these lakes.

So detailed is the information pertaining to each lake with the associated beaches, deltas, spillways and outlets that we have considered it best to sum up the history of the well-established lakes, chiefly with the aid of the accompanying maps.

The first stage represented in this series shows the Keene lake in the upper Keene valley and a portion of early Upper Newman along the extreme western edge of the map. The Keene lake left terraces, beaches etc. at the present elevation of 2100 feet or over. Upper Newman, at 1820 feet, probably drained westward. We believe that the Keene lake emptied south. The Elizabethtown-Lewis valley at this time was filled with ice, although marginal or subglacial drainage may have been active.

The second stage represents an early stage of Lower Newman lake at an altitude of 1740-80 feet. Ice still occupied the Elizabethtown-Lewis valley.

Lower Newman lake (1700-20) succeeded the above. This lake probably drained west. The western side of the Elizabethtown valley was occupied by the Rhododendron lake (1650 feet) the outlet of which was perhaps southward.

The next stage shows the early Saranac waters (1660 feet) in the west and the Bouquet lake (1530 feet) in the east. This stage
Plate 12

Delta level of Lake Vermont (marine level) cut by the Ausable Forks branch of the Delaware and Hudson Railroad, one mile and one-half northwest of Clintonville. Photograph by H. L. Alling in 1916.
Figure 13 Glacial lake succession in the Ausable quadrangle. Stage 4. The Newman lakes were succeeded by the Saranac glacial waters, an early stage of which is shown, altitude 1660 feet at present time. It drained eastward into the Bouquet lake (1530 feet).
Figure 14. Glacial lake succession in the Ausable quadrangle. Stage 5. The branch lake at 1270–1300 feet followed the Bouquet. It received the drainage of a middle stage of the Saranac glacial waters, 1600 feet elevation.
Figure 15  Glacial lake succession in the Ausable quadrangle. Stage 6. Lake Pottersville (of Miller) followed the Branch lake (1060) when the Saranac waters had fallen to 1500 feet.
Figure 16 Glacial lake succession in the Ausable quadrangle. Stage 7. The detailed history of the Elizabethtown-Lewis valley has not been fully deciphered, from this stage to stage 9. The Wilmington lake filled the Keene valley and discharged eastward through the Gulf, forming the cataract plunge basins such as Copperas pond.
Figure 17 Glacial lake succession in the Ausable quadrangle. Stage 8. Lower Jay lake succeeded the Wilmington lake at an elevation of 1000 feet. It is not certain what was the history of the area to the east. Moffittsville lake is shown on the northern margin of the map (after Taylor).
Figure 18 Glacial lake succession in the Ausable quadrangle. Stage 0. This map shows a portion of Lake Vermont or the Marine level. The elevation of the extensive terrace and beaches at Ausable Forks is 647 feet.
marks the change of direction of drainage in the outlet of the Ausable valley series from westward to eastward. It was from this point on until stage 8 that the channels in the Ausable quadrangle were cut.

The Branch lake (1270–1300) appeared at the time a middle stage of Saranac waters filled the western part of the area here mapped. Lower Saranac waters followed and the Branch lake was succeeded by Lake Pottersville (1060 feet). Only a portion of the latter is shown as it extends south for 30 miles below the margin of the map. This is one of the longest glacial lakes so far found in the Adirondacks, excluding the Hudson-Champlain valley lakes.

The succeeding stage shows the Wilmington lake (1100 feet) in the Keene Valley-Ausable river valley. Its drainage was through the Gulf. This river produced the cataract plunge basins, of which Copperas pond is the best example. The history of the Elizabethtown-Lewis valley during this and the following stage is imperfectly known but a number of levels have been recorded as ranging from 1018 down to 710 feet through six intermediate levels. Until these can be satisfactorily classified and correlated it is best to defer suggesting the possible geography of these stages.

Following the Wilmington lake, the Lower Jay lake (1000 feet) occupied the Keene valley area. To the north is Lake Moffittsville, which is based upon terraces noted and described by Taylor.

In the last map of the series (stage 9) we picture Lake Vermont (the marine waters of Fairchild). This body of water correlates the levels noted by Kellogg and Ries at Elizabethtown with those of the Ausable Forks area.

Below the 647 foot level of Lake Vermont there are in the northeast corner of the sheet definite levels at about 500 feet elevation which have been recorded by Woodworth and others. These may very well be marine in origin, and the connection with the sea may have been through the St Lawrence river depression.

It is not our purpose to convey the impression that this series of sketch maps represents the complete and absolutely correct

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140a Since the above was written, it is believed that confusion of stream and glacial lake terraces has been made. A series of lakes rather than a single lake may have occupied this valley at this stage.
141 Taylor, F. B., Amer. Geol., v. 19, 1897, p. 392-96.
history of these glacial lakes; they represent rather the present status of the problems connected with the physiography and glacial geology of this portion of the Adirondacks.

ECONOMIC GEOLOGY

The mineral resources of the Ausable quadrangle consist, so far as yet developed, of magnetic iron ore, building or monumental stone, and graphite. The iron ore mines are not at present operated, but in their day were important sources of ore. As time passes and magnetic concentration becomes more and more widely applied, the old mines whose richest and most accessible ore has been sought in earlier years may again furnish to concentrators the lower grade portions, not touched by the early operators. The quarries for the beautiful green granite, which has been described under the Algoman syenite series, can supply an unlimited amount of the stone when one of this color is called for. The graphite deposits are as yet in the stage of prospects, but are deserving of serious consideration and treatment. In the subsequent pages all three are described and discussed both from the economic standpoint and as problems of scientific interest.

Magnetite Deposits

It was originally planned that D. H. Newland, until recently Assistant State Geologist, should contribute a section to this bulletin dealing with the magnetic iron ore bodies within this area. During the summer of 1919 Mr Newland entered the field for a week with the junior author, visiting the principal mine workings. It has not been possible, however, to carry out the original plan. Mr Newland has offered many valuable suggestions and has discussed very freely many details concerning them. We have made very free use of his published papers especially New York State Museum Bulletin 119. We are greatly indebted to him for aiding us in these matters.

History. Ore was first discovered in 1806 upon Arnold hill. Attempts were shortly made to mine the deposit in a small way. In 1812 the property was purchased by Arnold, Stickney and Howe, who held title to the hill for over 50 years. The early workings were located on the southern extension of the bodies, of which the Finch pit was the most important opening. Still farther south, apparently to the east of the main belt of ore, is the Chalifou pit,
which was not more than a prospect pit. As mining operations continued the northern extension of the belt of ore was exploited.

North of these southern pits is the Arnold mine or Big pit. It was the largest producer of all of the mines in this district and for many years was the main supply. About 1896 the main shaft was lost by caving, preventing any further operations underground. No attempt has ever been made to reopen the mine.

The northern end of the Arnold hill belt is marked by the Nelson Bush mine. This mine was the last to be operated. The Arnold Mining Company reopened it in 1903 but ceased operations 3 years later, although they had constructed a mill of 200 tons daily capacity. It is understood that Witherbee, Sherman and Company of Port Henry now hold title to the property.

Across the gorge of the Little Ausable river, east of Arnold hill are the Cook hill mines, which recently have been explored by diamond drilling. South of the Cook pits are the Mace, Winter and Burt pits. The latter is mentioned by Ebenezer Emmons in 1842 but has not been located by us. We conclude that it was not more than a prospect pit.

South of Palmer hill, a mile and a quarter north of Ausable Forks is an old opening, now caved in.

The period of active operations on Palmer hill began about 1825 and lasted until 1890. Many open pits, slopes and inclines have been made along the southern face of the hill. The eastern series of these workings was opened by the Peru Steel and Iron Company, while the others were developed by the J. and J. Rogers Company. North of Palmer hill the topography merges into a broad ridge of which Jackson hill is the summit. Along this ridge a few pits and open cuts have been excavated. Still farther north in the Dannemora quadrangle are the Rutgers and the Dills and Lavake pits which were for a time small producers of ore.

There are other belts of magnetic ore within the quadrangle. In the township of Chesterfield, and in the Hale brook property, magnetic surveys have revealed the presence of ore, but they have never been investigated. In the ridge northeast of Cross a small pit 6 feet wide, by 10 feet long and 10 feet deep has been opened on a streak of hornblende and magnetite. Northeast of Clements mountain, in the southwest corner of the quadrangle, there is an old pit of pyritous magnetite, but the deposit seems too limited and too high in sulphur to demand serious attention.

**Forges and blooms.** One of the earliest attempts to employ magnetic separation in this country was made upon Palmer Hill.
ore in 1836. A large tailing pile exists today near the eastern end of the line of pits on the hill, as a reminder of the old days. Apparently the attempt was not wholly successful as gravity methods were subsequently used.

The Arnold Mining Company, built in 1903 a mill at Arnold station on the Ausable Branch of the Delaware and Hudson Railroad (Ferrona on the map) having a daily capacity of 200 tons of crude ore. It was equipped with magnetic separators of the Ball-Norton drum type.145

The size to which the ore was crushed depended directly upon the granularity of the iron and gangue minerals. A fine-grained ore necessitated fine grinding. Extreme fineness was avoided when possible because of the attendant cost and of the difficulties produced by very fine ore in the blast furnace. Crushing was never carried to the extent where the maximum recovery of magnetite was effected. A serious difficulty of many of the ores from this district is their hematitic (martitic) nature. Martite, theoretically pure Fe₂O₃, is nonmagnetic. Some of the Arnold hill ores contain a very large percentage of martite which is not recovered by the magnetic processes alone. The presence of this mineral may have been one of the causes for the abandonment of the mines. It is quite possible that by a combination of gravity, flotation and magnetic methods a satisfactory recovery could be secured. Whether such methods could be made financially successful in order to compete with ores that are more readily handled is an open question. The Arnold Mining Company found that a little less than two tons of crude ore were required to make one ton of concentrates.

In the early days ore from Palmer hill and Arnold hill was sent to forges at Black Brook, Ausable Forks, Clintonville, Lower Jay, and to a point on the Little Ausable river. In some cases the ore was first roasted to render it friable and then crushed by stamps and passed over jigs. The forges, charcoal blooms and the small rolling mill at Ausable Forks produced a mild steel which was in demand for the manufacture of nails, wagon tires and crucible steel. Considerable amounts were shipped to Pennsylvania to be made into crucible steel. It is obvious that when steel was produced directly from the ore without the intermediate product of pig iron, the quality of the steel depended directly upon the composition of the ore itself. It was well recognized that certain pits

furnished an ore best suited for special purposes. The development of Black Brook, Clintonville and Lower Jay was directly dependent upon the iron industry and when it waned in 1890 the population of these towns declined. Ausable Forks was able to maintain its former position by the establishment of the large paper and pulp mills.

In the old days the demand for charcoal and lime for the iron forges produced an industry that gave employment to many men. Some of the old roads, now rapidly becoming impassable, were made for transporting oak logs to the charcoal kilns. Some of the limestone exposures have been located through information obtained relating to the old quarries where the lime was secured.

**Mines.** *The Arnold hill group. The Chalifou pit.* This was one of the earliest pits opened in this region. It is through Emmons' report that we obtain our information. It is located a mile and a half southeast of the Finch pit on a different belt or band of ore from the others of this group. The ore is reported as having a thickness of 8 to 12 feet. The accompanying analysis\(^1\) shows a low titanium and low sulphur ore:

<table>
<thead>
<tr>
<th></th>
<th>Fe(_2)O(_3)</th>
<th>FeO</th>
<th>SiO(_2)</th>
<th>TiO(_2)</th>
<th>S</th>
<th>P(_2)O(_5)</th>
<th>Al(_2)O(_3)</th>
<th>MnO</th>
<th>CaO</th>
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<td></td>
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<table>
<thead>
<tr>
<th></th>
<th>Iron</th>
<th>Phosphorus</th>
<th>Manganese</th>
<th>Titanium</th>
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</thead>
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<tr>
<td></td>
<td>48.35</td>
<td>.188</td>
<td>.122</td>
<td>.295</td>
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A recast of the ore minerals shows that the ore was principally magnetite, very little, if any, martite being present.

*The Finch pit.* This working, originally about 75 feet deep, now caved in, was opened on the belt of ore that continues northward where open pits appear high upon the southern slope of Arnold hill. The following analysis shows a high martite ore:

<table>
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<tr>
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<th>FeO</th>
<th>SiO(_2)</th>
<th>TiO(_2)</th>
<th>S</th>
<th>P(_2)O(_5)</th>
<th>Al(_2)O(_3)</th>
<th>MnO</th>
<th>CaO</th>
<th>MgO</th>
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<td>7.87</td>
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<td>.24</td>
<td>.45</td>
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<td>.67</td>
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<tr>
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</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>Iron</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>63.27</td>
<td>.196</td>
</tr>
</tbody>
</table>

The ratio of martite to magnetite is calculated to be nearly 2 : 1

*The Indian and adjoining pits.* North of the Finch pit are the Indian and other pits which furnished ore before the discovery of the larger bodies to the north. On opening the large deposit these

1 Analysis supplied by S. Le Fevre.
pits were abandoned. According to Emmons' report the pits were situated upon four parallel deposits, the richest of which, known as the "blue vein," was 2 to 8 feet wide and composed in large degree of martite. The large percentage of the steel-blue mineral is indicated by inspection of the accompanying analysis: 147

<table>
<thead>
<tr>
<th></th>
<th>Fe₂O₃</th>
<th>FeO</th>
<th>SiO₂</th>
<th>S</th>
<th>P₂O₅</th>
<th>Al₂O₃</th>
<th>MnO</th>
<th>CaO</th>
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<tr>
<td>Phosphorus</td>
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</tr>
<tr>
<td>Manganese</td>
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<td></td>
</tr>
<tr>
<td>Titanium</td>
<td>0.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

By 1842 this bed had been worked to a depth of 260 feet for a length along the strike of 500 feet. The parallel beds are separated from each other by the ore formation granite. One of these, the "black vein," is given as 3 to 11 feet wide and chiefly composed of magnetite with a little martite. A third member of the group is the "gray vein" which varied in thickness from 2 to 8 feet. To the west of this group is another which was developed only in a small way, as it was of poor quality.

The Arnold mine. This was the largest producer of all of the mines in the Arnold group. The deepest workings were about 800 feet. Below the surface the underground drifts were reached by means of two shafts about 500 feet apart. They were driven down the dip of the "gray vein." The other belts or bodies were reached by cross cuts. Drifts at different levels along the strike extended for 700 feet. It is stated that the ore bodies narrowed appreciably near the bottom, a condition similarly obtaining in the Nelson Bush mine to the north. From the reports of Putnam and Smock 148 we gather that the Arnold mine was opened upon northern extensions of the bodies to the south, and had the same parallel bodies, the "blue," "black" and "gray veins." The ore-formation granite separating the beds is about 40 feet thick in each case. The strike of these bodies is N 35° E and the dip is 70° west at the surface but at the 325 foot level the beds flatten to 55° and eventually to 40° at the bottom of the workings.

The "gray vein," to the east, is 3 to 25 feet thick, the "black vein" in the middle is from 3 to 27 feet in thickness and the "blue

vein” to the west has about the same dimensions. The marked differences in the character and composition of these three closely associated bodies is of both commercial and scientific interest. As their local names imply, the “black vein” is a magnetic ore, while the “blue vein” is martitic. The contrasts are explained in the section of the present bulletin devoted to the geology and origin of the magnetite ore bodies. The ore of the “blue” band is seamed with vein quartz and ferruginous calcite. Two analyses of the “blue” ore are here quoted:

<table>
<thead>
<tr>
<th></th>
<th>Fe₂O₃</th>
<th>FeO</th>
<th>SiO₂</th>
<th>TiO₂</th>
<th>S</th>
<th>P₂O₅</th>
<th>Al₂O₃</th>
<th>MnO</th>
<th>CaO</th>
<th>MgO</th>
<th>Cu</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>a83.14</td>
<td>5.27</td>
<td>7.64</td>
<td>.26</td>
<td>.035</td>
<td>1.72</td>
<td>.31</td>
<td>1.08</td>
<td>.005</td>
<td>.003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b85.54</td>
<td>2.39</td>
<td>7.36</td>
<td>.16</td>
<td>.43</td>
<td>2.71</td>
<td>.98</td>
<td>.48</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\*

<table>
<thead>
<tr>
<th>Total</th>
<th>Iron</th>
<th>Phosphorus</th>
<th>Manganese</th>
<th>Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>a100.634</td>
<td>62.30</td>
<td>.232</td>
<td>.24</td>
<td>.256</td>
</tr>
<tr>
<td>b100.05</td>
<td>61.74</td>
<td>.188</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reasonable Recast of No. A

Ore minerals

Martite ........................................ 69.55
Magnetite ....................................... 17.00
Ilmenite .......................................  .46

Sulphides

Chalcopyrite .................................... .011
Pentlandite .................................... .009

Gangue minerals .................................. 12.77

In complete analyses by Beck\(^{150}\) of the ores of three bodies are here reproduced:

<table>
<thead>
<tr>
<th>“Black Vein”</th>
<th>“Blue Vein”</th>
<th>“Gray Vein”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>71.50</td>
<td>98.00</td>
</tr>
<tr>
<td>FeO</td>
<td>27.00</td>
<td>2.33</td>
</tr>
<tr>
<td>SiO₂</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td></td>
<td>Tr.</td>
</tr>
<tr>
<td>MnO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insol.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cook hill mines. The ridge to the east of Arnold hill contains several bodies of ore, which Emmons states are four in number. The smaller bands are from 1 to 3 feet in thickness, while the important and larger ones are from 6 to 13 feet in dimension. They were first developed a few years prior to 1838 by the Peru Steel and Iron Company. They were last worked in 1856. The ore was sent to forges on the Little Ausable river. The bodies strike northward and dip about 80° west. The ore is more involved with hornblende and biotite than is the case with the other mines in the Ausable quadrangle. Pyrite and apatite are locally abundant though the average run of the pits seems to be below the Bessemer limits.

\(^{149}\) No. a, S. Le Fevre; No. b, George W. Maynard.
\(^{150}\) Beck, Lewis C., Mineralogy, 1842, p. 18.
Analyses of Cook hill ore follow:\textsuperscript{151}

\[
\begin{array}{lcc}
\text{Fe}_2\text{O}_3 & 60.226 & 57.857 \\
\text{FeO} & 27.486 & 29.314 \\
\text{SiO}_2 & 7.640 & 5.400 \\
\text{TiO}_2 & .410 & .492 \\
\text{S} & .033 & .037 \\
\text{P}_2\text{O}_5 & .052 & .023 \\
\text{Al}_2\text{O}_3 & 1.269 & 3.960 \\
\text{MnO} & 1.104 & .515 \\
\text{CaO} & 1.100 & 1.560 \\
\text{MgO} & 1.587 & .846 \\
\hline
\text{Total} & 99.907 & 99.540 \\
\text{Iron} & 63.536 & 63.300 \\
\text{Phosphorus} & .023 & .010 \\
\text{Manganese} & .081 & .040 \\
\text{Titanium} & .246 & .295 \\
\text{Magnetite} & 87.250 & 83.89 \\
\text{Martite} & .238 & .000 \\
\text{Ilmenite} & .779 & .93 \\
\text{Pyrite} & .065 & .07 \\
\text{Apatite} & 1.123 & .11 \\
\text{Gangue} & 11.545 & 14.44 \\
\hline
\text{Total} & 100.000 & 99.54
\end{array}
\]

Recently Witherbee, Sherman and Company, have been exploring the Cook hill deposits with diamond drills, and have opened numerous prospect pits. The magnetite is relatively free from martite but is cut by diabase dikes and a plug of gabbro. These dikes strike N 50° E. Slight faulting seems to have occurred in connection with the intrusions of the dikes.

The Battle mine. This lies about 1½ miles north of the Cook mines proper, along the continuation of the same ore bodies. Emmons states that the ore exists as two parallel deposits, although only one band had been definitely proved at the time of his visit. This mine was last operated about 65 years ago. The workings consisted of an open cut 600 feet long and 10 to 20 feet wide. The ore shows much variation in richness and possesses a sheeted structure undoubtedly due to movement subsequent to ore formation. Slickensided surfaces are common. The gangue of the ore is composed of biotite as its essential mineral. It is believed that the deposit is closely involved with the Grenville strata and that the biotite is to be considered as derived from a sedimentary original.

Five commercial analyses are here given:\textsuperscript{152} The highest titanium content of no. 5 is regarded by Newland as traceable to titanite and not to ilmenite.

\textsuperscript{151} Supplied by James Berkes.
\textsuperscript{152} J. N. Stower, James Brakes.
The nonseparation of ferrous and ferric irons render it impossible to calculate the percentage of the ore minerals present.

The Winter mine. This old mine is located southeast of the Cook hill group about 1½ miles northeast of Clintonville, and east of Lilly pond. There are three or more small bands of ore striking slightly west of north in a nearly vertical position. The band principally worked is about 10 feet wide. The southern end has been mined by open cut methods, while further north the ore has been reached by a slope driven into the hillside for 100 feet where it connects with an adit driven from the east. As nearly as can now be ascertained (considerable slumping having occurred) the ore flattened to almost a horizontal position. Several dikes of diabase cut the ore in a diagonal position and complicate the actual field conditions prevailing there. An incomplete analysis shows a siliceous ore:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>52.10</td>
<td>60.70</td>
<td>52.80</td>
<td>39.90</td>
<td>61.20</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>.012</td>
<td>.008</td>
<td>.029</td>
<td>.028</td>
<td>.012</td>
</tr>
<tr>
<td>Sulphur</td>
<td>.035</td>
<td>.021</td>
<td>.035</td>
<td>.019</td>
<td>.026</td>
</tr>
<tr>
<td>Titanium</td>
<td>.225</td>
<td>.495</td>
<td>.225</td>
<td>.225</td>
<td>2.076</td>
</tr>
</tbody>
</table>

Thin sections of the ore show that the gangue has the mineralogy of the ore-formation granite. The magnetite does not appear to have been transported from elsewhere but to represent a magnetite-rich phase of the ore-formation granite.

The Mace mine. A little north of the Winter workings is a small deposit formerly worked as an open cut some five hundred feet long and from 3 to 10 feet wide. The ore is quite similar to the Winter ore, possibly not so rich.

The Palmer hill group. Palmer hill proper. High upon the southern face of Palmer hill are many open pits, slopes, drifts and irregular openings that were operated and developed by two companies from 1825 to 1890. The Peru Steel and Iron Company controlled the eastern extension of these pits, while the J. and J. Rogers Company mined the ore on the western end of the outcrop. The Elliot slope is located on the southwestern side of the hill and pitches northward, following a band of ore 9 feet thick. Nearby and higher up the hill is the White Flint slope, likewise trending north with a 70° dip at first but flattening in depth. The band of ore is about 20 feet thick. These pits are indicated on the

accompanying plane table map of Palmer hill as pits Nos. 21, 22, 23, and 24.

Pits Nos. 19 and 20 are considered to be slopes to the Big pit. These workings appear to be located upon a different zone of ore from the above; and to be upon the ore zone that extends along the southern face of the hill. This set of workings is the deepest of all the mines in this district, being bottomed at a depth of 2200 feet, down the slope. The Summit pit, as its name implies, was farthest up the hill. It is credited with a depth of 1000 feet and dips about 30°. The Little pit, paradoxically, is the largest of all, and was opened by the Peru Steel and Iron Company. The length of the slope is 1200 feet and follows a band of ore 10 feet thick for 100 feet along the strike.

Figure 19  Stadia plane table topographic map of Palmer hill, showing abandoned magnetite iron ore mines. The figures apply to the pits and the six diabase dikes are lettered from a to f. The Roman numerals refer to the sections reproduced in figure 20. The rock is the ore formation granite of Algoman age, except the dikes. H. L. Alling, 1920.
The ore of Palmer hill is rather fine and quite similar to that from Lyon mountain. The gangue is composed of the minerals of the ore-formation granite though pegmatitic quartz and augite are plentiful in certain pits. Garnet occurs in others, rendering the ore very refractory. Fluorite granite as horses is found in one pit (no. 18 on the map) and seems to interrupt the ore.

The following analyses have been furnished by W. Carey Taylor. No. 1 and no. 2 are crude ore of the Peru Steel and Iron Company. No. 3 is that of concentrates produced by the same company.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>46.152</td>
<td>49.757</td>
<td>67.274</td>
</tr>
<tr>
<td>FeO</td>
<td>20.735</td>
<td>22.354</td>
<td>30.224</td>
</tr>
<tr>
<td>SiO₂</td>
<td>31.700</td>
<td>26.134</td>
<td>3.000</td>
</tr>
<tr>
<td>S</td>
<td>0.008</td>
<td>0.016</td>
<td>0.080</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.005</td>
<td>0.916</td>
<td>1.165</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>1.076</td>
<td>1.531</td>
<td></td>
</tr>
<tr>
<td>MnO</td>
<td>0.037</td>
<td>0.090</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td>3.64</td>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>0.872</td>
<td>0.229</td>
<td></td>
</tr>
</tbody>
</table>

Total 100.949 101.342 100.743

Iron 48.43 52.22 70.60
Phosphorus 0.002 0.008 0.007

Calculation of the percentages of the ore minerals shows that these particular samples were entirely free from martite.

Jackson hill mines. On the ridge north of Palmer hill, upon the western slopes of Jackson hill a number of old pits were opened in the early days upon two or three parallel ore zones. These strike about N 20° E with a high dip to the north. The two main pits are each about 500 feet long and from 10 to 12 feet wide. The maximum depth reached was 100 feet. The ore is quite similar to that from Palmer hill and said to have been of good quality.

Geology of the magnetic iron ores. In former years geologists ascribed a sedimentary origin to the Adirondack magnetic iron ores. While there may be some commercially important ores to which such an origin might be ascribed, yet those within the limits of the Ausable sheet are in all probability the product of igneous processes. The recognition of the igneous character of the country rock of these bodies of magnetite has caused the emphasis to be placed upon their magmatic or igneous relations.

In attempting to arrive at a reasonable conception regarding the mode of origin of the iron ores it is necessary to examine the stage setting of not only those with which we are immediately concerned, but that of other magnetite deposits in the Adirondacks. In this
Figure 20  Series of sections of main ore-body on Palmer hill, from Rogers slope on the southwest to the Peru company's pits on the northeast. The sections are sketched directly across the pits and by their varying directions from N 70° E to N 70° W, bring out the curving strike. The varying dip is also brought out. The long axes of the ore-shoots pitch down to the northeast, but in the large way the ore is a synclinal trough. The sections were drawn by J. F. Kemp in 1898.
survey of the conditions prevailing in and around the iron ore bodies we have received invaluable aid from Newland,\textsuperscript{154} Kemp\textsuperscript{155} and Miller\textsuperscript{156} to whose writings acknowledgment is made.

It is possible to classify the ores into two great classes; the titaniferous and the nontitaniferous magnetites. There is a commercial as well as a scientific basis for such a subdivision. The former are potential while the latter are actual ore reserves. The titaniferous ores are found in relatively basic rocks, such as the anorthosites and basic gabbros; while the nontitaniferous magnetites are found associated with acidic rocks such as the ore-formation granite of the Ausable sheet; or with members of the Grenville series, as in the limestone of the Western Mine near Keene Center\textsuperscript{157} where the ore is in a contact zone along with lime-silicates.

It is clear that in the present discussion we are dealing with that type which is associated with acid eruptives. In surveying the stage setting of these important deposits we are impressed with the fact that the ore occurs as impregnated zones without sharp boundaries in soda granite. The bodies can not be described as lenses, beds or lenticular masses. In the case of Palmer hill in this quadrangle and Lyon mountain farther west the belts of ore can be traced over some miles but the magnetite is not continuous over the entire distance, the ore occurring in several distinct masses whose strikes overlap each other.

A very persistent feature of the zones of ore is the general parallelism of the foliation of the enclosing rocks and the ore itself.

Pegmatitic stringers, magmatic veins of quartz, feldspar and augite are so persistently associated with this type of ore that Miller\textsuperscript{158} stresses their importance as a significant fact in the consideration of the origin of the ore. Lyon mountain, Palmer hill and Arnold hill are seamed with them. Allanite, fluorite, tourmaline and zircon are commonly found in these pegmatites.


\textsuperscript{156} Miller, W. J., Magnetic Iron Ores of Clinton County, N. Y., Econ. Geol., v. 14, 1919, p. 509–35.

There are additional references to be noted here that have appeared since the above was written, in Econ. Geol. by Nason, Newland, Miller and Alling.


\textsuperscript{158} Miller, W. J., Econ. Geol. v. 14, 1919, p. 516.
Another type of rock rather characteristically associated with the magnetites is a coarse hornblendic variety which especially favors the footwall, but into which at the ends the lenses of ore may pass. More or less quartz and feldspar, especially plagioclase may be associated, and the components are all so coarse that an origin, as some sort of igneous after effect, closely associated with the production of the ores themselves would at once occur to an observer. It is no more difficult to have iron-magnesia-alumina silicates produced by after igneous effects, than pure bases in the form of iron ore. Coarse masses of magnetite are involved in the general mixture, and the rock largely constitutes the lean or waste material thrown out on the dumps of the mines. Small prospects have at times been based on these hornblendic streaks. At Mineville, in the Elizabeth-town quadrangle, where the largest of the Adirondack nontitaniferous mines are situated, there are extensive piles of waste rock of this character around the mouths of the old slopes in the upper or Barton hill series of ore-bodies.

There is also in the footwall of the ore-bodies and a little distance away from them a pipe of typical Algoman gabbro, which one might at first suspect of having some connection with the hornblendic rocks, but which most probably has none. The coarse hornblendic rocks contain at Mineville a variety of minerals, often in large and well-developed crystals. Scapolite, garnet, titanite and small zircons with P, 3P3, and the prisms of the first and second order, have been collected. The acid pegmatite dikes also have zircons, which, however, are bounded by P, 3P and the unit prisms of the first and second orders but lack the zirconoid, 3P3. Similar minerals with a few additions have been noted and described from Lyon mountain by Whitlock.

These hornblendic rocks are exceedingly difficult to understand. It is quite possible that the allanite, fluorite, tourmaline and zircons occur in some of the basic pegmatites. These pegmatites are composed of andesine and black-green augite as essential minerals. Some of the other varieties of this hornblendic rock may represent igneous segregations in the ore-formation syenite-granite itself and again they may be partially digested inclusions either of the orthoamphibolites of Keewatin (?) age, or of paramphibolites of the Grenville series. Still another view is that they are in part products of magmatic activity upon segregations or inclusions within the

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country rock and thus could be referred to as skarn. The rocks on Palmer hill that can be grouped in this class appear to be limited to the basic pegmatite type.

The mines at Palmer hill in the Ausable sheet are not so productive of well crystallized minerals but in a large way are reminiscent of Barton hill. Hornblendic rocks of nearly this sort appear associated with the magnetites of Swedish Lapland at Gellivare, where they have been studied by the senior writer. As elsewhere in Sweden they are called skarn. An origin by much the same after effects as produced the ore itself is the generally accepted explanation for Gellivare, although in southern Sweden where associated sediments accompany some ore bodies, the skarn is referred to contact effects upon them.

The Barton hill ore-bodies present another interesting parallel with Palmer hill, in that at the Lovers Pit, much white, vitreous fluorite has been met, carrying disseminated magnetite throughout its mass. A long tunnel driven some years ago well down the dip intersected a strong vein or local mass of the fluorite, some feet in cross-section. While not a rock making mineral or found as a rock-component in the ordinary sense, yet the association with magnetite in apparently contemporaneous formation as an “after effect” of igneous action, is of much interest.

In Norway Brøgger\textsuperscript{160} reports that fluorite occurs both as an early separation in the augite syenites (quartz nordmarkites) and also as a contact mineral.

A contrasted interpretation has been given by W. J. Miller to hornblendic rocks encountered in close association with the deposits at Lyon mountain. The amphibolites are believed to be inclusions of older rocks, and the ore itself is explained as arising from reactions produced upon them by the inclosing granitic magma. In these partially assimilated forms their distinction from similar masses of calcareous Grenville blocks is a most difficult task. Consequently we do not wish to exclude the possibility that some of them may be of Grenville age. That the Grenville sediments are known to be associated with the magnetic ores in a few places is stated above. The Cook hill deposits in the Ausable sheet are also involved with Grenville strata.

The relationships obtaining on Palmer hill possess unusual significance in demonstrating the igneous origin of the ores. There is no

\textsuperscript{160} Brøgger, W. C., Zeitschr. Kryst. Min., v. 16, pt. 2, 1890, p. 56.
surface indication of the present or former existence of any Grenville or metagabbro rocks in or near the mines. It is, of course, possible that some of these ancient rocks have been assimilated by the intrusive with such complete absorption and digestion that it is impossible to recognize them. This field observation is considered by us as throwing considerable doubt upon the importance that Miller attaches to the metagabros as a source of the iron. We are inclined to the view that Miller has emphasized a feature not common to all the Adirondack bodies of this general type, for on Palmer hill there seems to be present every other condition similar or practically identical with that existing on Lyon mountain.

The ore itself is an aggregate of magnetite, microcline-microperthite, oligoclase, quartz, aegirite-augite, biotite, pyrite and apatite. Frequently the ferromagnesian minerals are more or less decomposed into serpentine, chlorite and carbonates. Martite, a variety of hematite, is found in many ores, Arnold hill ore being especially rich in this mineral.

This brief survey of the general conditions prevailing in and around the deposits of nontitaniferous magnetite associated with acid eruptives can be summed up as follows: The country rock is a soda granite, presumably of Algoman age. The presence of pegmatites, magmatic quartz veins, is so common as to be almost universal. The metagabbro and Grenville sediments are frequently but not necessarily associated with them.

The Palmer-Jackson hill deposits. The general character of the ore-formation granite has already been noted. The predominant rock appears to be a normal soda granite except that the usual dark silicates, the ferromagnesian minerals, are to a large degree lacking, their place being taken by magnetite and titanite. The feldspars of the ore-formation granite are, in the order of abundance, microcline-microperthite, soda-microcline, and albite-oligoclase. In the microperthite the potash component is in excess over the soda phase. The pyroxene is emerald green under the microscope and is soda bearing, probably aegirite-augite ranging to a soda-bearing diopside. Hypersthene is quite frequent. Titanite, zircon, apatite, pyrite and occasionally a little olivine complete the list. A few cases have been noted where the plagioclase exceeds the microperthite in amount and rarely is it absent; therefore, this phase of the rock approaches, in composition, a quartz diorite.

The ore-formation granite is quite distinctive and separable from the soda granites which are more closely associated with the syenite
the granite frequently shows a marked foliation which assumes a crude parallelism with the strike of the impregnated zones that constitute the ore, but this feature is less conspicuous farther away, because of the lower magnetite content of the rock, although the microscope reveals a well-developed foliation. Petrographic study points to the conclusion that the foliation was due in part to original magmatic flowage—a deuteritic\textsuperscript{161} crushing action—and in part to subsequent orogenetic disturbances resulting in cataclastic structures. The latter have been superimposed upon the deutericiticlastic characters, rendering definite conclusions inadvisable regarding their relative importance.

The granite that constitutes Palmer, Jackson, Arnold and Cook hills is penetrated and criss-crossed by a great profusion of pegmatite dikes, magmatic veins, apiltes and silexite\textsuperscript{162} masses. These coarsely grained masses cut the granite and zones rich in magnetite and again in turn are themselves cut by stringers or dikelets of magnetite. This demonstrates that the pegmatitic-silexitic activity and the migration of the magnetite into stringer-like masses was periodic and oscillatory in behavior. As far as we have observed, these oscillatory processes were limited to the later magmatic or deuteritic expressions of the igneous activity of the ore-formation granite.

In composition these pegmatites vary considerably. The most common type is granitic, composed of soda-microcline, microcline-microperthite and quartz. Frequently these carry magnetite in perfectly formed crystals. Another pegmatitic development which is much more basic, is made up of andesine, quartz and dark pyroxenes. These carry in addition to the magnetite the bluish black martite. The silexite masses are still later and form ramifications of nearly clear milky white quartz. Still later, and apparently in the dying phase of the igneous activity, appeared ferruginous carbonate vein-like masses that produce a strikingly banded ore of black magnetite, steel blue martite, white quartz and maroon colored calcite. The order of events seems to be that above suggested.

\textsuperscript{161} Deuteric, proposed by Sederholm, J. J. Bull. de la Comm. Geol. de Finlande No. 48, July 1916, p. 141-42, for changes, usually metasomatic, "which have taken place in direct continuation of the consolidation of the magma of the rock itself."

\textsuperscript{162} Miller, W. J., Science, new ser., v. 49, 1919, p. 149. "Silexite" for any body of pure or nearly pure silica of igneous or aqueoigneous origin which occurs as a dike, segregation mass, or inclusion within or without its parent body.
Another phase of the pegmatitic activity is in the development of a large mass of fluorite granite which cuts the ore-formation granite of Palmer hill. Today it forms one of the "horses" left by the miners as a pillar to support the hanging wall. Newland\textsuperscript{163} says that the fluorite granite is "particularly in evidence in the walls of the Big pit and in a belt which can be traced north from the pit for 150 feet. The . . . rock has a granitic texture and in other respects is analogous to an acid intrusive . . . (The fluorite) forms irregular grains of about equal size with the feldspar and quartz and intercrystallized with them. Where most abundant it constitutes from 20 to 50 per cent of the rock." It is thought that this fluorite granite is very closely associated with the ore-formation granite and probably antedates the majority of the pegmatites.

Some interesting minerals are found in these pegmatites, allanite, black tourmaline, titanite, fluorite and soda-bearing blue-green actinolite suggestive of arfvedsonite, have been noted. These ramifications, dikes etc. have produced in a few instances slight contact

\textsuperscript{163} Newland, D. H., N. Y. State Mus. Bul. 119, p. 100.
effects upon the ore-formation granite, yielding garnet, wernerite, serpentinized or chloritized augite and sericitized feldspar.

A study of the ores, both in thin section and in etched polished slabs, shows that the magnetite is often replaced by martite, while in other cases the two iron minerals are apparently intergrown as though the result of simultaneous development.

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Figure 22 Camera lucida drawings showing martite replacing magnetite. A Petrographic thin section from Arnold hill. (100th). Silverman Illuminator x 100.
B Etched polished slab of ore from Skiff mine. Paradox lake quadrangle. Silverman Illuminator x 100. Etched with concentrated HNO₃.

In dealing with iron ores containing both magnetite and martite it is necessary to understand the relation of the two minerals to each other. There are two views concerning this relation: One is that the two are isomorphous, forming a series of solid solutions. Sosman and Hostetter have reached the conclusion that solid solutions in the system hematite-magnetite exist in nature. They say that ores “intermediate in composition between Fe₂O₃ and

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\[\text{FIGURE 22: Camera lucida drawings showing martite replacing magnetite. A Petrographic thin section from Arnold hill. (100th). Silverman Illuminator x 100. B Etched polished slab of ore from Skiff mine. Paradox lake quadrangle. Silverman Illuminator x 100. Etched with concentrated HNO}_3.\]
Fe$_3$O$_4$ (FeFe$_2$O$_4$) are more common than is generally supposed.” Martite is found as a component in a solid solution with magnetite and in the same specimen exists as a pseudomorph after magnetite. Opposed to this is the view that the two minerals are not soluble in each other but coexist as intergrowths. Broderick$^{165}$ has pointed out that caution is necessary before accepting the solid solution theory. The writers, while working with etched polished slabs, have been impressed with the fact that both zonal structures and intergrowths frequently exists in magnetite. While these observations appear to be incompatible, it must be remembered that the relations above

noted may be the result of several distinct processes. The Lake Sanford titaniferous ore consists essentially of ilmenite and magnetite which are believed to be primary intergrowths suggesting a solidified eutectic. In quite a similar way magnetite and martite are intergrown in the Arnold hill ore. Both minerals are probably the result of magmatic processes. On the other hand, similar aggregations are clearly the result of subsequent metasomatic or deuteric replacement. Assuming that a system composed of two completely soluble components crystallized from a magmatic melt in the form of a solid solution and was subsequently attacked by liquid solutions rich in one of these end members, metasomatic replacement could result in the formation of intergrowths. Thus it is possible to have intergrowths in a perfect soluble series, and conversely, it is possible to have zonal structures in a eutectiferous system. Consequently it is of prime importance to ascertain whether the minerals are due to primary or subsequent processes.

A third interpretation is that magnetite and hematite (martite) are partially soluble in each other in a way strictly analogous to Warren's (who follows Vogt) conception of the relationship between orthoclase and albite. We base this interpretation upon the fact that we have found distinct variations in the color of magnetite in specimens taken from different mines and between magnetite crystals in contact within the same specimen. This difference of color exists in spite of similar orientation as shown by the parallelism of replacements along parting planes. The phenomena indicate solid solutions but not necessarily a completely soluble series. The finding of intergrowths apparently of primary origin suggests a eutectiferous system. Our view would, it is believed, fit the facts as observed, which the other two concepts seem to fail to explain.

In addition to the normal magnetite and martite in the Ausable ores there is an iron-bearing mineral the composition of which we have not fully ascertained. Under the usual type of vertical illuminator, using either direct or artificial light rendered similar to daylight by passing it through Corning daylight glass, the magnetite is faint creamy brown in color, the martite is creamy white or grayish white while the unknown mineral possesses a distinct

brownish tint. If a Silverman illuminator\textsuperscript{170} is employed, the magnetite is steel gray, the martite bluish black, while the unknown mineral (called by us the "rusty brown magnetite") is brown black in color. This brownish metallic mineral is certainly older para-

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure24}
\caption{Camera lucida drawings showing relations of Magnetite, "rusty brown Magnetite," and Aegirite-augite in ore-formation granite. Petrographic thin sections. \textit{A} From 2 miles east southeast of Clintonville (Specimen 1070). \textit{x} 100. \textit{B} From Palmer hill. Pyroxenic phase of ore-formation granite (Specimen 353). \textit{x} 100.}
\end{figure}

genetically than some of the magnetite as the latter has been found surrounding it. In some cases the impression created was that the magnetite has been deposited upon it. In figure 24A a camera

\textsuperscript{170} Manufactured by Ludwig Hommel and Company, Pittsburgh, Pa. It consists of an annular lamp (of daylight glass) encircling the objective furnishing a cone of oblique light which is reflected up the tube of the microscope.
lucida drawing illustrates the genetic relation between this brown metallic mineral and augite. In the slide it is seen that a grain of augite is apparently replaced by the brown mineral. The latter shows boundaries that are continuous with the crystal faces of the pyroxene. In figure 24B a crystal of augite (aegirite-augite) is shown partially altered to "rusty brown magnetite" accompanied by the formation of serpentine. Both of these examples demonstrate that there is a genetic relation between the decomposition of aegirite-augite and the formation of the "rusty brown magnetite."

The Arnold-Cook hill deposits. The conditions on Arnold hill are in general very similar to those obtaining on the Palmer-Jackson hills with the additional factors of the presence of the metagabbro. A thin section of a hornblendic rock secured from the mine dump is interpreted by one of us as metagabbro. When Newland described the deposits on Arnold hill in 1906 all such rocks were considered to be representative of the Grenville series. Consequently he says:

"A black hornblende gneiss is encountered on the walls of the Nelson Bush mine and may represent an included band of the sedimentary gneisses to which it corresponds in composition."

On Arnold hill there is considerably more martite in the ore; one body chiefly composed of this mineral, being known as the "blue vein," as recorded in the reports of Putnam and Smock. The country rock shows considerable variation in composition. Some slides show that the potash feldspar is exceeded in amount by the acid plagioclase and in a few cases, may be lacking entirely. Biotite and occasionally a little pyrite are found associated with the magnetite. The latter is especially true of the Cook hill deposits. Red jasper and the ferruginous calcite are much more prominent on Arnold hill than on Palmer hill.

To the north of the shafts inclusions of metamorphosed Grenville arkose were found which under the microscope proved to be distinctly clastic in character. Other xenoliths of Grenville have suffered more or less complete assimilation resulting in a rock possessing the mineralogy of the syenites (quartz nordmarkites). While it may be that there is some syenite which we failed to see present on Arnold hill, we are inclined to believe that this syntectic

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rock has been interpreted as syenite by Newland, but he says: "It is here quite different in appearance from the (Ausable Forks area), having a mottled aspect which is induced by the abundant hornblende mixed with feldspar." It may be that some of the streakedness of the Mineville syenite-granite is due to assimilation of Grenville material. Kemp says: "Both in the drill cores, as well as in the field, we find a quick passage from the usual variety (of syenite) to the basic with no eruptive contact that would indicate a separate intrusive mass or an included sediment." The conception of partially digested Grenville material would perhaps furnish a reasonable clear explanation of both of these occurrences.

The deposits on Cook hill are clearly and directly associated with the Grenville strata, resulting in rocks indicative of contact action, rich in augite, hornblende, biotite, and pyrite. The sedimentary masses are apparently long included stringers, but too small to be shown on the map. These seem to be biotitic and hornblendic varieties of the Grenville series.

**Origin of the ores.** In dealing with magmatic ores of this character it is strongly believed that "magmatic differentiation has been, no doubt, a prominent factor in the early [the italics are ours] stages of their formation and perhaps is competent to explain the whole course of their development. Yet there is reason for believing that other [our italics] agencies were active in producing the final result. Of these the influence of highly heated vapors and waters arising from the igneous mass has been most important. The occurrence of fluorite, apatite, hornblende etc., intercrystallized with the magnetite, is suggestive along this line, as well as the frequent accompaniments of pegmatite and vein quartz. This agency would be especially active in the final [the italics are again ours] stages of cooling and consolidation of the wall rocks. In some cases it may have been the determinative factor in bringing the iron minerals into their present [our emphasis] position." Kemp also believes that the pegmatites were functional in the ore-formation process. "In the walls of Old Bed (at Mineville) pegmatitic developments are characteristic of the edges and limits of the ore. . . . They seem in some way to be associated with it in origin."

Newland’s views are very suggestive, and in view of the information we have subsequently secured we feel much inclined to voice our concordance with his opinion. We would, however, emphasize

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174 Kemp, J. F., N. Y. State Mus. Bul. 119, p. 64.
the importance of the magmatic influences such as the pegmatitic and silexitic activity in causing a migration of the ore into concentrated masses as they are now found. This view has been strengthened by studies suggested by the examination of etched polished slabs. This work in connection with the usual petrographic studies shows that it is possible to unravel many details not revealed by other means.

*Miller's hypothesis.* The important rôle played by the pegmatitic and silexitic activity has been appreciated by Miller\(^{177}\) in the origin of the Lyon mountain deposits. Here the included masses of metagabbro and Grenville strata have been injected by the ore-formation granite (the Lyon mountain granite of Miller) and in part partially assimilated. This alteration of the metagabbro and Grenville rocks, according to Miller, took the form of a reaction upon the hypersthene and hornblende of these foreign bodies resulting in a paragenetic change to a diallage of lower iron content with a liberation of iron oxides. Miller, therefore, believes that the granite secured the iron from these older rocks through assimilation and by virtue of the reaction above noted, and subsequently concentrated by the action of the later pegmatites. This implies that the magnetite did not come from the granite itself but from these foreign bodies. Miller gives the results of chemical analyses of the iron content of the unaffected metagabbro and the diallage rock and shows that that of the former is slightly in excess of that of the latter. The crucial point in Miller's hypothesis is whether there was a sufficient amount of the metagabbro digested by the granite to have furnished the ore. Miller fails to give any suggestion relating to this point. Many of the areas of gabbro shown on his sketch map are some distance from the ore-bodies themselves and are not pure gabbro, for they are given as "gabbro and gabbro-granite mixed rocks." If the magnetite has been produced by this process it is inconceivable that the granite should not have assimilated or digested the gabbro much more effectively than is indicated by Miller. From his description of the Lyon mountain granite we gather that it is a normally clean rock free from much admixture. "In the Palmer hill district to the east of Lyon mountain the rock is nearly a pure feldspar-quartz-magnetite mixture, and in the writer's [Newland, as well as ours] observation that is the prevailing character of it . . . Palmer hill and many other mines exemplify their association with granite notable for its small amounts of the dark minerals, except magne-

If there is any value to be attached to Miller's theory it should be applicable to other deposits of the same general type, like that of Palmer hill as well as Lyon mountain. But we seriously question whether there was or is a sufficient amount of metagabbro or Grenville material injected, assimilated or reacted upon by the granite to have produced the amount of ore actually known to exist. "Such a theory also fails to account for the iron content of the granite in its normal phases. This is a matter that has not been dealt with, but it needs to be taken into consideration. . . . The rock belongs to the general type of soda-rich granites and syenites that (are) . . . the predominant magnetite-bearing rocks the world over."179

While Miller deserves credit for a careful study of one of the Adirondack deposits and has pointed out some features that have not been noted before, we agree perfectly with Newland "that he has over-emphasized certain features which really play a minor rôle in the ore-formation process."

All the evidence that we can muster from the literature, field and laboratory observations shows that the ore has assumed its present position during a late stage of the magmatic activity. The concentration of the magnetite was in part due to actual replacement of the ore-formation granite by magnetite, which in turn has been replaced by martite. This magmatic metasomatic replacement seems to have been a dual process. Magmatic vapors of corrosive nature altered the feldspars and the pyroxenes to secondary products. These evidently were more readily replaced by the magnetite than the unaltered minerals. An exception to this is quartz. In figure 21 two camera lucida drawings show magnetite replacing quartz.

The production of the "rusty brown magnetite" from the alteration of the pyroxenes of the ore-formation granite suggests certain phases of Miller's theory. It may be that a little ore has been derived in this manner, but we are confident that the significant fact attached to the "rusty brown magnetite" is that it performed a precipitating influence in the deposition of the magnetite from magmatic solutions.

The majority of the martite is clearly the result of still later magmatic solutions; veins of milky quartz, jasper and ferruginous calcite are the last effects of the magmatic activity. All these minerals also appear at Mineville in the same relations.

This, however, does not touch the problem of the actual source of the iron itself. Palmer hill is significant in that if we attribute the formation of the ore to magmatic differentiation we have a most perfect example of ores formed by this means. If the Ausable quadrangle ores have been derived in this manner, as we believe, the question arises: What caused the ore-formation granite to differentiate where it did? We have stressed Palmer hill because of its relative simplicity but for an answer to this question we must consider Arnold hill and Cook hill. Here the presence of metabasalt and Grenville masses are found. It is quite possible that they were more or less directly responsible for the differentiation. This may have been caused by assimilation, that is, magmatic differentiation by assimilation, or through the effects of chill, causing the crystallization of the heavy minerals of the granite (which in this case are chiefly magnetite) in accordance with the operation of Soret’s principle. Still a third explanation is that the metabasalt and Grenville blocks were catalytic agents, remaining nearly passive but furnishing the stimuli for the process of differentiation.

Another possible function performed by these foreign bodies is in stimulating pegmatitic development. It is a matter of constant field observation that pegmatites are frequently associated with inclusions. If this be applied to the genesis of the magnetite ores it may be that the foreign rocks not only were influential in locating the place for the differentiation of the granite and in starting the process but causing a pegmatitic development of such a magnetite so that the magnetite derived from the granite by differentiation was concentrated by them.

Paragenesis of the ores. Our conception of the ore-formation process can be summed up as follows:

1 A soda-granite possessing abnormal amounts of magnetite in the place of the usual ferromagnesian minerals, differentiated, producing local concentrations of magnetite.

2 This differentiation may have been stimulated by the presence of metabasalt and Grenville strata through (a) assimilation, (b) effects of chill-Soret principle, (c) Catalytic action.

3 Slight contact action took place by reaction of the granitic magma upon floating xenoliths of metabasalt and Grenville masses or upon solidified portions of itself, causing further separation and concentration of magnetite from the magma.

4 Presence of xenoliths stimulated pegmatitic activity which in turn caused an extensive alteration of feldspars and pyroxenes of
the solidified granite. These gases may have found weak zones in
the rock, parallel with the magmatic flowage lines.

5 The decomposition of pyroxene was accompanied by the for-
motion of "rusty brown magnetite."

6 Acid pegmatites carried magnetite, either directly from the
magma in solution or redissolved magnetite from the concentrated
masses due to differentiation to zones already affected by the cor-
rrosive gases.

7 The magnetite replaced the quartz and decomposed feldspars,
and was deposited upon the "rusty brown magnetite," by deuteretic,
metasomatic processes.

8 Relatively basic pegmatitic activity attacked the previously
formed magnetite causing its partial replacement by martite. This
action was localized, certain ore bodies being more affected than
others.

9 Renewed acid pegmatitic and silexitic activity without much
effect upon the ores.

10 Magnetitic and martitic replacement repeated through periodic
and oscillatory operation of these processes.

11 Slight and local disturbances resulting in microfaulting and
brecciation.

12 Introduction of veinlets of jasper that cut all previously
formed matters.

13 Dying magmatic activity took the form of circulation of waters
charged with iron and carbonate forming compounds. Ferruginous
calcite veins seamed the ore bodies.

Note in March 1925. The manuscript for the present bulletin was com-
pleted in the spring of 1920. In the interval of awaiting publication the valu-
able and suggestive bulletin by R. J. Colony on the Magnetite Iron Deposits
of Southeastern New York, N. Y. State Mus. Bul. 249-50, 1923, was issued.
Had it been available during the formulation of the views expressed above,
important reference would have been made to it. We would like to note
here, however, the many close parallels between the conclusions of Professor
Colony and those reached by us.

Building Stone

Stone for buildings and for monumental purposes has been ob-
tained from three of the igneous rocks as represented on the map.
The most extensively developed is the acidic quartz-bearing phase of
the rocks formerly classed in the Syenite series but which we have
called quartz-mordmarkite on the map. Five quarries have been
opened within a mile east and a mile south of Ausable Forks. The
anorthosite has received attention between the two highways on the
east bank of the east branch, southeast of Stickney Bridge. Finally,
to a less extent than either of the above, the ore-formation granite has been utilized for a red granite about 2 miles east of Ausable Forks on the Clintonville road. All these quarries are described in detail by D. H. Newland, in Bulletin 181 of the New York State Museum, on the Quarry Materials of New York, pages 82–98, 1916.

**Syenite or quartz-nordmarkite.** This rock is a handsome, dark green variety of several shades of color. It takes a fine polish, gives good contrasts between polished surface and inscriptions, and is well suited to monumental work.

In the quarry the stone is parted by series of joints, not spaced unduly closely, but affording large rectangular blocks. The texture of the stone is massive, affording but occasional traces of flowage lines. Microscopically it consists of the minerals fully described under quartz-nordmarkite, on a previous page. Mr Newland records for the stone from the Moore quarry, the first one east of Ausable Forks: specific gravity, 2.71 or 169 pounds a cubic foot; crushing strength, 14.734 pounds a square inch; ratio of absorption, .155 per cent or .26 pounds a cubic foot.

A striking example of this dark green stone can be seen in New York City, in the unique sphere, forming a memorial sun dial, just across 116th street from the library of Columbia University. The sphere is of polished stone, seven feet in diameter and is without checks or cracks.

**Anorthosite.** This can be obtained in many parts of the quadrangle as is shown by the map, but has received especial attention just southeast of Stickney Bridge. The rock is the granulated variety in which only remnants of the original labradorite crystals survive. The stone is greenish-gray in color and gives a pleasing impression in ashlar. Mr Newland records for it: specific gravity 2.75 or 172 pounds a cubic foot; crushing strength, 14.735 pounds a square inch; absorption, .127 per cent.

**Ore-Formation granite.** This has a red color and is peculiar in having the dark silicates of normal granite replaced by magnetite, which is stated by Mr Newland to constitute about 15 per cent of the rock. The development of the stone as yet consists of one small opening, two miles east of Ausable Forks on the Clintonville road.

**Graphite**

Graphite is a notable constituent of many of the limestone exposures within the quadrangle. It also occurs in two quartzose formations of the same Grenville series: the "Dixon" and the Bear
pond schists. The "Dixon" is the only commercially important source of the mineral. Although no shipments have been made from any of the deposits there are several districts which have been prospected. The chief district, situated to the southeast of Trout pond, is owned by George W. Smith of Keeseville. The ore here consists of a stratum averaging 10 feet thick containing from 8 to 14 per cent of graphite. The chief mineral of the "Dixon" is quartz while the remainder of the rock consists of biotite, feldspar, pyrite, pyroxene and occasionally a little zincblende.

The Grenville rocks have been folded into a northward pitching anticline so that the "Dixon" schist outcrops in the form of a letter $U$. Along this $U$ several pits have been opened. Igneous influences have greatly complicated the conditions prevailing upon the property and deserve careful consideration in connection with commercial possibilities. The ore from the two main pits situated on the eastern limb of the anticline is superior to any found elsewhere in the Adirondacks. The percentage of the graphite is exceptionally high; the individual flakes are large and the mica content correspondingly low. Unfortunately this high quality is localized, failing to constitute the entire thickness of the "Dixon" schist, as it occurs in several distinct horizons separated by barren yellow quartzose rock. Petrographic examination of this yellow quartzite seems to indicate that this is in part igneous material. If this is so it is probably referable to the Algoman nordmarkite-soda granite. We interpret this alternation of rich graphitic schist and barren rock to the removal of graphite or its parent carbon mineral, from the latter zones by pegmatitic (pneumatolitic) activity, and its concentration near by, resulting in zones rich in graphite. Pits along the western limb reveal a lower grade of ore. Mica, pyrite, garnet and diopside occur with a lower graphite percentage. The garnet and the diopside are considered significant in that they imply incipient contact action. Experience has shown that such action frequently renders the "Dixon" schist too variable and too difficult to crush without reducing the size of the flake in the production of a commercial grade.

South of the Smith property proper the "Dixon" reappears associated with the Chesterfield, the Trout pond, Swede pond quartzites and the Catamount schist. The character of the "Dixon" as a graphite ore in this area has not been investigated.

The Gulf Prospect. The area at the eastern end of the Gulf was prospected many years ago for graphite. The graphite occurs in two different kinds of rocks. First and most important, the bottom
layers of the lower Swede pond quartzite contain a small percentage of large sized flakes. A chemical analysis by H. F. Gardner formerly of the New York State Museum showed 2.12 per cent. The second mode of occurrence is much more spectacular and consists of large flakes and semi-amorphous masses produced by pegmatitic action upon the Trout pond limestone. This is the type that drew the attention of the prospectors to the district. The mineral is found along the margins of pegmatites of the soda granite, in the pegmatized Trout pond formation, which in places is somewhat amphibolitic. It also occurs in similarly affected portions of the upper Swede pond. The presence of graphite in basal layers of the lower Swede pond strongly suggests the presence of the "Dixon" schist although it has not been found to outcrop in the district.

Cherry glen prospect. A very similar type of deposit which received attention some years ago is situated on the western slope of Jay mountain. The graphite is entirely of the pegmatite-contact type and possesses no commercial possibilities, although interesting museum specimens can be secured from the deposit.

A prospect pit in the southwest corner of the quadrangle was opened a number of years ago by lumbermen who were attracted by large "books" of dark brown mica. A basic pegmatite cuts through the anorthosite and has developed mica and graphite. The latter occurs in large flakes, a few of which are the size of a 25-cent piece. The rock in which the graphite occurs is a typical contact rock composed of diopside or augite, wernerite and graphite.

Origin of graphite. The deposits of graphite within the Ausable quadrangle possess peculiar significance in determining the mode of origin of the mineral, a question in regard to which there are many divergent answers.

We can best commence our discussion by examining the normal "Dixon" and Bear pond schists. Their persistence and uniformity both along the strike and dip, and their conformity with the associated strata of the Grenville series leave little doubt that these graphitic schists are distinct and normal formations within the Grenville sediments.\(^{180}\)

It seems, therefore, quite clear that the "Dixon" represents a metasandstone which originally itself contained remains of primitive nonvascular plants such as algae, or was associated with bituminous shales, now altered to schists. Changes in this material probably

\(^{180}\) Bastin, E. S., Origin of Certain Adirondack Graphite Deposits. Econ. Geol., v. 5, p. 134.
resulted in a thick oil or bitumen. It may be that the ancient sands saturated with oil or bitumen were similar to commercial petroleum bearing sands of today. The Bear pond schist was very probably a shale. The argillaceous substance and silica, under the influence of metamorphism, combined into feldspars, micas etc. Under subsequent heat and pressure as the result of mountain making stresses or static metamorphism the bituminous matter lost its hydrogen, nitrogen and water by volatilization resulting in amorphous carbon. This form of carbon was recrystallized by metamorphism perhaps assisted by igneous activity to its present form of flake graphite.

Thus the graphite of the "Dixon" and Bear pond schists as well as that of the limestones is regarded as organic in origin.

The pegmatitic-contact type of graphite presents a more difficult problem. In 1917 one of us reached the conclusion that this form was the result of inorganic processes, suggesting that either carbon dioxide or carbon monoxide as gaseous constituents of the Algoman nordmarkite-soda granite or gabbro magmas was the source of the carbon. A reconsideration of the entire problem of origin in conjunction with the study of the Ausable sheet deposits suggests that too great emphasis was assigned to the inorganic theory. In reviewing the deposits of the Adirondacks and especially of those discussed here we are impressed with the fact that when the pegmatitic-contact type is encountered there is either direct or indirect evidence that the "Dixon" formation occupied a position beneath the deposit. It is strongly believed that the pegmatites of nordmarkite-soda granite or gabbro parentage secured the graphite from the "Dixon" and deposited it upon the contacts with the overlying formation. The overlying formations most effective in furnishing the necessary reagents for this reaction are the limestones, especially the Trout pond. As far as has been observed such an explanation would be applicable to all the pegmatite-contact and fissure vein deposits in the Adirondacks as well as to others described in the literature.\(^1\)

Mica

The prospect referred to above as occurring in the southwest corner of the quadrangle was primarily opened because of the presence of biotite. Large "books," some of which are 3 to 4 feet in size and a foot thick are evidently the result of basic pegmatitic activity. No commercial value can be attached to this occurrence.

\(^{181}\) Winchell, A. N., Theory for the Origin of Graphite. Econ. Geol. 1911, v. 6, p. 222.
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THE UTICA AND LORRAINE FORMATIONS OF NEW YORK

PART 2 SYSTEMATIC PALEONTOLOGY

No. 1 Plants, Sponges, Corals, Graptolites, Crinoids, Worms, Bryozoans, Brachiopods

by

Rudolf Ruedemann

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PREFATORY NOTE

The work on the Utica and Lorraine formations of New York, an instalment of which is herewith printed, was finished in 1919. Owing to the fact that numerous manuscripts accumulated for printing during the war, and to the unfavorable conditions for the printing of scientific reports since then, the manuscript has rested with other prepared material until now and it has been found necessary to print it in instalments. The first part, the stratigraphy of the Utica and Lorraine formations, is now being printed as Bulletin 258 of the State Museum. Number 1 of the second part, dealing with the systematic paleontology of the plants and lower classes of animals inclusive of the brachiopods, is hereby published. It is planned to publish later number 2, dealing with the systematic paleontology of the Mollusca, Crustacea and Eurypterida, and prepared by Dr E. O. Ulrich and R. Ruedemann.
THE UTICA AND LORRAINE FORMATIONS OF NEW YORK

PART 2 SYSTEMATIC PALEONTOLOGY

No. 1 Plants, Sponges, Corals, Graptolites, Crinoids, Worms, Bryozoans, Brachiopods

BY

RUDOLF RUDEMANN

PLANTS

Phylum Algae

Genus Buthotrephis Hall

Buthotrephis subnodosa Hall

Hall (1847, p. 262) has described and figured as Buthotrephis subnodosa supposed algal remains that are quite common in the Lorraine beds at Turin (whence Hall’s types came), Martinsburg, Lorraine, Pulaski etc.

They consist of branching “fronds,” the branches being “opposite or alternate, subnodulose or vesicular, obtuse at the extremities.”

From the fact that the branches are structureless, not regularly bifurcating but irregularly branching and frequently consisting of a thin argillaceous film sometimes slightly colored by carbonaceous matter, it is quite probable that these bodies do not represent the remains of seaweeds but branching borings of worms or other animals, who in quest of food tunneled closely under the surface from a main channel in various directions. I have seen similar markings made by insects boring in the wet sand along the shore of Lake Champlain.
Genus *Sphenophycus* Ruedemann

*Sphenophycus latifolium* (Hall)

The alga which has been described by Hall as *Sphenothallus latifolius* (1847, p. 262) from the "Hudson River group" at Schoharie, has been shown by the present writer (1912, p. 73) to be a fossil of Trenton or Utica age (Schenectady beds). The typical wedge-shaped form of *S. latifolius* has not been observed in either the Utica or Lorraine beds.

As Hall's genus *Sphenothallus* comprises two forms, one of which is related to the worms or to the conularids (*S. angustifolius*) and the other undoubtedly an alga, we have (op. cit. p. 73) restricted his genus to the first species and for the algal remains proposed the term *Sphenophycus*. As in a later publication (1916, p. 83) we came to the conclusion that *Sphenothallus angustifolius* Hall, belongs to the group of organisms for which the term *Serpulites* had been proposed by McLeay (Murchison's Silurian System 1839), and *Sphenothallus* as applied to *S. angustifolius* becomes a synonym of *Serpulites*, the question arises whether the generic term *Sphenothallus* should not then be transferred to the second species *latifolius*. This we consider inadmissible as leading to confusion, for a generic term clearly should stand and fall with its genotype.

*Sphenophycus lobatum* nov.

Plate 1, figure 1

The alga which we propose to name *S. lobatum* is composed of clavate lobes of different size but arranged so that the largest lobe is at or near the center and the others flanking it. The surface is entirely smooth save some traces of longitudinal (neural?) lines and small irregularly scattered granules of secondarily concentrated matter. Parallel to the distal edge, a distinct line is developed which separates a slightly beveled frontal margin from the main body.

The specimen here figured which is incomplete at the base and one side, has a length and width of 60 mm. Very similar lobate thalli were found in the Schenectady shale among the algal bodies referred to *S. latifolium* (Ruedemann, 1912, pl. 1, fig. 8).

*A Leptograptus annectans*, a rare fossil in the shale, is so placed in regard to the margin of the seaweed that
one can not help believing that it was attached to the latter and remained so when the thallus settled to the bottom.

**Horizon and locality.** Upper Utica (zone of Climacograptus pygmaeus) at Marcy creek, Oneida county, N. Y.

**Sphenophycus succulentum** nov.

The Utica shale, especially at Holland Patent, has furnished a variety of well-defined black carbonaceous patches of puzzling character. Some of these, owing to the presence of spicules, have been recognized as sponges, and others could be referred to eurypterids (see *Echinognathus walcotti*). There still remains, however, a residuum of large bodies of mostly lobate outline and thick carbonaceous test that can not be placed in any of the divisions of the animal kingdom, but agrees well with the organisms that we found to be very common in the Schenectady beds and that there have been, provisionally, lumped together as *Sphenophycus latifolium* (Ruedemann, 1912, p. 73).

We have before us large elongate ovate bodies, with slightly wavy margins attaining a length of 130+ mm that clearly spread out from a basis. They usually exhibit no texture or structure of any kind, but were originally smooth and are not folded and wrinkled as if shrunken before entombment. Some parts have become granular and are enriched with pyrite crystals, obviously the result of the decay of thick organic matter. In a few specimens the cuplike marginal cavities observed by the writer in *S. latifolium* and apparently connected with the neural system could be observed.

The carbonaceous patches, like the cephalopods etc., carry small Spirorbis and, therefore, were real organisms able to serve as bases of attachment to parasitic forms, and not merely accidental features. They always occur in deep black shale thickly charged with graptolites, a fact of considerable interest in view of the opinion now generally accepted that the majority of the graptolites belonged to the pseudo plankton and drifted about attached to seaweeds.

**Horizon and locality.** Upper Utica shale at Holland Patent. N. Y.
Genus **Discophycus** Walcott

**Discophycus typicale** Walcott

Walcott (1883, p. 19) has described and figured under the name of *Discophycus typicale* discoid bodies with a smooth, dark, lustrous surface, that occur in the upper Utica shale in the town of Trenton, N. Y.

James (1884, p. 128) considered these apparently structureless bodies as mud bubbles such as form on mud flats from liquid mud that is strong enough to stand considerable pressure without bursting. James is mistaken in this view, for a series of specimens of *Discophycus typicale* before us, some of these metatypes (identified from type locality by the nomenclator himself), leave no doubt that all these bodies are actual remains of organisms; but they also show that the monotypic term Discophycus, as well as the species, comprises a variety of things, namely, several sponges, eurypterid remains and also seaweeds.

*Teganium subsphaericum* Rauff (not Walcott) *Sycodictya rara* Ruedemann are sponges with subcircular outlines; the eurypterids *Pterygotus walcotti*, *Eurypterus rusti* may drift together into subcircular patches that fall under the definition of *Discophycus typicale* and finally also the supposed seaweed *Sphenophycus* may assume, though not typically, a subcircular form.

The type specimen of *Discophycus typicale* not having been located by us, it remains an open question to which of these fossils it belongs. There is, however, little doubt in our mind, from the study of such specimens as that reproduced in text figure 9 that it is incorporated in *Teganium subsphaericum* Rauff. The specimen mentioned (one of the metatypes of *Discophycus typicale*) is so completely flattened, that it forms a perfect subcircular disk, the former aperture being only indicated by the lack of gloss. Spicules (mostly dermalia) are found only after careful search and the delicate parietal skeleton is only retained in molds of the spicules near the margin.

Genus **Delesserites** nov.

**Delesserites salicifolia** nov.

Plate 1, figure 2

The upper Utica shale at Holland Patent, N. Y., has afforded a unique fossil possessing the following characters:
Description. Leaflike, lanceolate, flat body, incomplete at the basal end, 91 mm long and about 10 mm wide in the basal and middle part, tapering to an acute apex. Margin entire. Surface formed by an extremely tenuous carbonaceous and pyritous film. Along the center passes a strong, mostly straight, sometimes somewhat wavy midrib 1 mm wide, composed of a green powder, which under the microscope is seen to consist of minute pyrite crystals. From this project forward and outward thinner ribs, at an angle of about 40°, which reach the margin and are spaced about 7 mm apart in the middle of the thallus and closer in the distal portion; their arrangement is irregular, partly opposite and partly alternating.

From the deep depression which the body forms in the rock on the left side, it is inferred that the thallus was originally a thick sheet of firm gelatinous but not hard or horny substance.

Small pyrite nodules, irregularly scattered over the surface may represent fruiting proliferations.

Remarks. While it can not be proved that this fossil actually is the remains of an alga, and the algae have become the receptacle for altogether too many obscure Paleozoic fossils of uncertain origin, such as worm burrows and tubes, gastropod trails, etc., the consistence and structure of this fossil are of such a nature that they well agree with certain recent seaweeds, and at the same time do not suggest any other class of organisms.

It is only with considerable hesitancy that we have selected a new generic term for this alga and we should have much preferred to place it under one of the already existing terms, if this had been possible without unreasonably extending the scope of those already overburdened names.

The genera Buthotrephis, Chondrites and Haliserites suggest themselves here at once.

Schimper (1890, p. 61) unites Buthotrephis Hall and Chondrites (Sternberg) in his family Chondriteae, the thallus of which is characterized by being composed of several layers of cells, and divided into cylindric or slightly flattened lobes. Whiteaves (1897, p. 139) who describes a series of finely preserved flat, much divided seaweeds from the (Black-River or Richmond?) limestone of Cat Head, Lake Winnipeg, Canada, refers them to Chondrites but states that in the present state of our knowledge, it would seem that Buthotrephis can scarcely be satisfactorily distinguished from Chrondrites, adding that Goeppert (1859, p. 452) says, that the only difference between Buthotrephis and Chondrites is the flatter habit
of the thallus of the former, a character which, he says, is not always seen in Hall's figures of species of Buthotrephis. But the B. antiquata Hall, the species that is accepted as the genotype, is described as having subcylindric stems; and on the other hand, Chondrites is named after the recent Chondrus, which has a flat and lobed thallus.

Whatever their differences may be, our form can not be properly brought under either of these two genera, since they are devoid of midribs and veins.

Devonian algae which possess a ribbonlike thallus and distinct midribs have been referred to Haliserites Sternberg, as for example, H. dechenianus Goeppert, which is extremely common in the Devonian shales of Germany.

Steinmann (1911, p. 49) has found the fruiting proliferations of this seaweed and claimed it is a true Fucus and properly referable to the latter genus, while Schimper (op. cit. p. 68) has pointed out that Haliserites Sternberg is based upon very problematic plant remains from the Cretaceous sandstone of Germany and that the Devonian seaweeds can not be united with this genus. At any rate, our fossil is also readily distinguished from the Devonian Fucus (Haliserites) by the possession of veins, besides the midrib. In this feature, as in its outline, it suggests the recent Delesserias, Florideae of the northern Atlantic and Pacific which are distinguished by their brilliant coloring and leaflike thallus that possesses a midrib from which branches ("veins") are developed that proceed to the margin. We have for this reason proposed to name this alga Delesserites salicifolia (the specific designation chosen from the willow leaflike outline of the thallus).

**Genus Palaeophycus Hall**

**Palaeophycus fluctuans** nov.

**Text figure 1**

This name is proposed for a doubtful fossil collected by Doctor Ulrich in the Lorraine-Oswego transition beds in the wall beneath the Salmon river falls, 15 to 20 feet above the base of the falls.

It consists of a bundle of very flexuous bands or fibers sufficiently carbonaceous to discolor the greenish gray sandstone. The bundle, incomplete at both ends, is about 90 mm long and the single fibers

---

1 Since these do not function as the veins of a leaf but are merely thickenings that serve as supports of the lobes, they should be more correctly called ribs and the midrib costa, as is done by some authors.
are about 1 mm wide. There is no structure whatever visible in the fibers, the coarse grain of the rock helping to destroy what might have been there.

Figure 1 Palaeophycus fluctuans nov.

The fossil has all the appearance of a drifted mass of delicate, very flexuous seaweeds and is here merely placed under the collective name Palaeophycus, which comprises the unbranching, tubular forms, to avoid creating a new name for a very incompletely known fossil. Most species of Palaeophycus, the generic type included, are probably but worm tubes and burrows.

Genus Rhombodictyon Whitfield

Rhombodictyon irregulare nov.
Text figures 2 and 3

The upper Utica shale at Holland Patent contains large, irregular patches of carbonaceous matter that fail to show any structure except a system of parallel lines. These lines, while in the whole
very regularly parallel, are nevertheless seen in some places to anastomose or branch or intersect each other. While in some specimens the lines appear as furrows or rather fine cracks, separating the thick film of carbonaceous substance, in others they project like rods above the surface of the film. The direction of the parallel lines bears no relation to the shape of the organism, but is always the same in one specimen. The lines disappear gradually by fading out or in other specimens by breaking up into short fragments, in the thinner marginal portions of the film; and in some cases (see text figure 2) a broad, smooth margin surrounds the central lineated portion.

Figures 2 and 3 *R*hom*bod*ic*ty*on irreg*u*la*re nov. x \( \frac{3}{4} \) Original of figure 3 is the type.

We have no doubt that the parallel lines are but shrinkage cracks, sometimes secondarily filled by pyrite and thereby projecting as rods, that developed with the contraction of the organic bodies. The latter can be inferred from the relatively great thickness of the carbonaceous film to have been succulent algal bodies resembling somewhat the recent Nostoc. Walcott has recently (1919) made known a wonderful series of such primitive algae from the Middle Cambrian of British Columbia and thereby aided greatly to throw light on the mysterious sources of food of the profuse animal life of the Cambrian and Ordovician seas. It is certain that the deep black, carbonaceous Utica shale in which the bodies here described occur obtained a large proportion of its carbonaceous matter from just such primitive soft, gelatinous algal masses. It is for the reason that these bodies were so soft that while there is abundant carbonaceous substance present in these shales, one is so rarely able to see outlines of the plant remains. It is not to be doubted that the masses of soft algae that flourished in these early seas had to give
way under the attacks of the plant-eating animals to tougher forms such as prevail today, and many had already adopted long before Utica time the excellent and efficient remedy of secreting lime and becoming "calcareous algae."

Similar bodies of thick carbonaceous patches occur quite frequently in the Normanskill shale near Albany. These have a prevailing system of parallel lines, which are connected by fainter, more irregular, often oblique cross-lines. Whitfield (1886, p. 347) has considered this structure as that of a sponge and proposed the genus Rhomboidictyon for it and distinguished several species. From an inspection of his types and other material collected by us we have no doubt that these supposed sponges are based on like algal remains with shrinkage cracks. We have specimens in which the same system of cracks (or pyrite rods as fillings of such cracks) can be traced through neighboring graptolites, suggesting that the fine cracks really represent a minute cleavage that is not strong enough to develop in the hard shale but can do so in the more brittle carbonaceous plates.

Although we consider Whitfield's name as misleading in suggesting the sponge nature of the fossil, the laws of priority require its retention.

**ANIMALS**

Phylum **Coelenterata**

Class **Spongiae**

Order **Hexactinellida**

Family **Plectospongidae**

Genus **Cyathodictya** Hall & Clarke

(Cyathophycus Walcott)

The genus Cyathophycus Walcott was based on a form, _C. reticulatus_ that is very abundant in the upper Utica shale at Holland Patent, N. Y. Dawson proposed Cyathospongia as a substitute to avoid the perpetuation of the erroneous conception of the algous nature of the fossil that found expression in the name. That name, however, being preoccupied, Hall and Clarke proposed the term Cyathodictya (1898, p. 24) as one being in better harmony with the general terminology of the Hexactinellida.

Rauff, in his Palaeospongiologie has given a very full account of the history of the genus (1893, p. 250) and the following diagnosis of the same [translated]:

Slender, conical, single sponges, whose thin tubular wall incloses a deep paragaster, probably extending to the base, with wide osculum;
and is pierced by numerous parietal gaps (perhaps only paragastric invaginations). Probably with short basal tuft, consisting of delicate rods. The parietal skeleton consists of slender-rayed, plane stauractins with rectangular, or nearly rectangular crossing rays; often rudiments of a radial ray are seen. The principal stauractins place their rays alongside of each other, often to the next centers or even beyond. Therefrom originate vertically rising and horizontal ring-shaped skeletal bands composed of bundles of rays. One often counts in the bands of spicules three, four or even five adjoining rays, since the rays of the stauractins often are longer, than the meshes are wide and since besides them also single rhabds and smaller stauractins take part in the composition of the bands of spicules. The meshes are mostly filled with stauractins of smaller orders of size in normal orientation, which in fact arrange themselves into finer intercalated bands, but do not surround each other in the regular fashion of Protospongia. Along the upper margin of the sponge the skeletal bands are dissolved into a dense, confused, interwoven mass of stauractins and rhabds.

The genus is typically represented by C. reticulata which has been elaborately described by Rauff (op. cit. p. 252-4). It is further represented by C. quebecensis Dawson, from the black shale at Little Metis bay on the St Lawrence river, probably of Canadian age. We have also here referred with doubt a small tubular type of sponge, from the Canajoharie shale of the Mohawk valley as C. tubularis (1912, p. 75) and Bassler (1915, p. 318) would place in this genus also the sponge described by Rauff as Dicthyophytra (?) walcotti, an associate of C. reticulata in the Utica shale at Holland Patent, (see below p. 18). We have also before us another sponge from the uppermost division of the Utica shale which is probably a Cyathodictya.

**Cyathodictya reticulata (Walcott)**

Plate 4, figures 1-4

Rauff (op. cit. p. 252ff.) describes this species as follows [translated]:

Inversely acute conical, in the upper half nearly cylindrical. The size of the individuals varies between 10 and 120 mm in height, and 4 to 35 mm in diameter. The latter lies a little below the upper margin, which is slightly contracted. The lower extremity is pointed. A basal tuft has not been seen in our material, but Walcott, Dawson and Hinde state that basalia are present. The thin wall is perforated by numerous circular parietal gaps which lead into the paragaster extending to the base. The principal skeletal bands form rectangular meshes, which in the larger specimens are about 3 mm high and 2 mm wide, and
decrease in size downward proportionately. Between these principal bands and parallel to them, finer bands occur which decrease by steps and are composed of stepwise smaller stauractins: in such a fashion that in general, there is intercalated medially between each two principal bands (H in figure) one band of medium thickness (n₁) and between this and the neighboring principal band a still finer band of the third order (n₂). The secondary bands often appear abruptly interrupted, but this may be due to the preservation. Between these bands there are found, partly isolated, and partly also associated bandlike still smaller stauractins of several orders of size, which produce a still further division of the skeleton.

Hinde (532, p. 66) states that the vertical skeletal bands project more sharply than the horizontal. I could not find this, nor was it found in a more accurate drawing of the bands with the camera. But the strength of the principal bands often changes a little in some stretches; according to the number of rays which participate in any place in their composition. This number varies between 2 and 6. As one sees from plate 3 figure 2 stauractins, which properly belong to the median bands, often also enter with their vertical and horizontal axes into the bundles of the principal bands and a corresponding behaviour of the smaller stauractins of a higher order is seen in the intermediate bands. Besides one often finds longer and shorter rhabds, for which cross rays can not be found, and one must assume, that these were originally present as slender rhabds in the bundles and bands the same as in recent forms. Sometimes a median band becomes as strong as the principal bands, or conversely a principal band as thin as a median band. Altogether there occur various abviations from the dominant rule.

The vertical bands bifurcate close above the basal point, while a bifurcation, conforming to the general shape of the sponge, is rather rare. But also some of the annular bands divide under acute angles; the new bifurcation pieces thus produced form in some places diagonal connections between two superjacent rings, in other places they may return into the old rings; this not being observable on account of the reverse side, but known in the recent Euplectellidae.

At the upper margin of the sponge there is a zone 5–10 mm wide, in which the bands dissolve into a confused, dense, felted mass that is composed of medium-sized, small and very small stauractins that are placed partly normal, partly diagonal. Also in this felted mass one can trace long, straight, or still more slightly and gracefully curved bands; but as a rule they are distributed without any definite relations to each other. Close to the margin numerous small rhabds in longitudinal and transverse positions seem to be incorporated into the skeleton. This dense, felted mass probably served to strengthen and thicken the delicate oscular margin of the very thin-walled tube.

1 It is here, however, to be remembered, that it is uncertain whether principal and secondary bands originally were in one layer; that it hence remains doubtful whether these axes, originally lying above or below the principal bands, have not been appressed to these subsequently.
The vertical axis of the great stauractins in the principal bands measures 2–4 mm; the horizontal axis is much shorter corresponding to the elongate rectangular shape of the meshes, but also the reverse proportion occurs. The thickness of the rays is 30–50 μ at the intersections; the rays taper gradually thence to a point, are straight, slightly bent or S-shaped as also the bands are often slightly wavy. The stauractins of the median bands (n1) are, on an average, one-half to two-thirds the size of those of the principal series, but there also occur in these intermediate bands stauractins of the first order, as well as much smaller ones. The smallest, still distinctly visible and measurable stauractins had an axial length of about 100 μ. Besides these there were undoubtedly present also numerous, much smaller sarcode spicules. Traces of a fifth ray are seen frequently.1

The circles designated as parietal (?) gaps before, have a diameter of about 1 to 1½ mm. Their distance, measured from center to center, is 2 to 4 mm. Although not regularly distributed, they show a distinct inclination to alternate arrangement. Their transverse series are more distinct than their longitudinal ones. The upper dense marginal zone lacks them, and also the basal portion seems to be without them. They appear now, whether the counterplate is torn off or not, as slightly projecting hollows, or more rarely as circular depressions, which have the black color of the slate, while the surrounding portions of the wall appear colored yellowish from a porous film of pyrite that is spread out between the stauractins and does not show any structure. It is still doubtful whether such a film (dermal layer) was present originally, or whether most minute sarcode spicules, or sarcode and surface spicules, were cemented together in the process of pyritization through addition of pyrite. The latter case is the more probable.

The parietal gaps are not distinct in all specimens (not at all in the smaller ones). They seem then to lie hidden under that pyrite layer. Nor are they surrounded by skeletal bands, as is the case in recent Euplectellidae, but on the contrary frequently crossed by them. It is therefore possible that they are not real parietal gaps, that is, complete perforations of the wall, but paragastric invaginations of the wall, or deepened depressions of the inner surface.2 At any rate they constitute a characteristic feature, and whatever may be their true nature, they seem to me to indicate, in conjunction with the general habit of the sponge and the arrangement of the skeleton, the close relationship of Cyathophycus with the Euplectellidae (Euplectella Owen or Holascus F. E. S.)3

It would be difficult to add any observations to this most painstaking description of the interesting Utica sponge. It undoubtedly

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1 I have, in a small area, cut off the pyritized layer, but could not find any traces of radial rays below.
2 In the recent Tegeria pulchra F. E. S. such pitlike hollowings on the inner surface are indeed in many cases, at a later period, artificially opened and converted into canals, which pass completely through the wall. F. E. Schulze, Hexactinellida, Chall.-Rep. v. 21, p. 94.
3 Euplectella has parietal gaps, Holascus paragastric invaginations.
makes the latter the best known Paleozoic sponge. Hall and Clarke, while not describing this species in the Monograph of the Hexactinellida, have furnished a series of figures that illustrate various growth-stages and the short basal tuft. If we add a few observations from the material in the State Museum, it is done with a view of bringing nearer to a solution the problems still left in the structure of *C. reticulata*.

Of the greatest importance are a few specimens which are not so completely flattened as the majority but where sufficient mud entered between the spicules to keep them in their original relative position.

These specimens show that the continuous film consists of a mass of most minute spicules, mostly stauractins (see plate 4 figure 2) which lay in a different layer than the principal skeleton, in some cases undoubtedly on the outside. The different rays of the large stauractins, which by their juxtaposition form the vertical and horizontal bands, lay originally in the wall of the sponge for the most part at least, above one another instead of side by side, as apparently in the compressed material, and it must be inferred from such parts of the tissue where the latticework of smaller stauractins (second and third order) has been preserved in a slightly divergent direction from that of the principal stauractins that they lay in different planes of the original sponge tissue, the smaller sets of stauractins probably above the principal ones.

At the upper margin the principal latticework continues close to or directly to the margin (see plate 4 figure 3), but it is buried under a dense mass of stauractins, which are a continuation in larger form and greater number of the small stauractins of the outer layers of the other portions of the sponge.

Near the base occur not only the stout basalia, but also extremely long and slender rhabds that surround the basal portion like twisted willow osiers, obviously to strengthen this important portion of the sponge against being broken off (see plate 4 figure 1).

The larger specimens show as a regular feature the "aureoles" or parietal gaps. No trace of these is seen on the outside of the specimens where the entire skeleton with the layers of smaller outer spicules is preserved. Nor do they show any relation to the latticework of the skeleton which is not pierced by them. As a rule, they are only surrounded by their pyrite film formed by the minute sardoce spicules, suggesting that they were only paragastric invaginations, but in a few cases at least, we have also seen them sur-
rounded by a ring of larger rhabds, indicating that they may have, at times, developed into parietal gaps.

In a specimen where sufficient mud entered the paragastric cavity to keep the two walls separate after compression, a rim 3 to 4 mm wide is left free of the intercalated layer of shale. This may give an approximate measure of the thickness of the wall when all tissues were still present.

The size attained by some specimens considerably surpasses that of Rauff’s material. One specimen, not complete at the top, is 26 cm long and over 9 cm wide.

**Horizon and locality.** Known only from the upper Utica shale at Holland Patent, Oneida county, N. Y.

**Cyathodictya (?) walcotti (Raufif)**

Raufif (1893, p. 249) has described a fragment of a large, coarse-meshed species, quite distinct in size and texture from its associate *Cyathodictya reticulata*, as *Dictyophytra (?) walcotti*. His description, translated, is as follows:

The slab of black slate, reproduced on plate 4 figure one, is covered with a rectangular network, which consists of pyrite, and through its extent indicates a sponge of large dimensions. The band forming the reticulum is but lightly impressed into the shale, so that where the pyrite is missing, shallow furrows result. The latticework shows vertical and horizontal bands of the first and second order, not everywhere of the third, and scatteringly also such of the fourth order. The bands of the first order form quadratical meshes 5 to 6 mm wide, or more elongate areas measuring 5 to 6 by 7 mm. These areas are subdivided. The bands exhibit a very fine longitudinal striation which, however, is for the most part, quite indistinct, in some places like a cross striation, also outside of the points of intersection, so that, for instance, horizontal bands show besides the horizontal striae also vertical ones, and vice versa. These fine striae or threads mostly have no smooth, continuous surface; this often appears interrupted, since the threads consist of series of (cubic) grains of pyrite. Possibly this fact alone causes the cross striae present in some places. The single threads are about 50 μ thick. They appear also in the bands of a higher order; but it was impossible to establish whether they are the rays of stauractins or simple rhabds, or whether both together compose the bands. Neither could we decide, whether or not the smallest stauractins are single scattered spicules. As the drawing shows, the reticulum (latticework) is partly filled by a macerated film of pyrite. This did not show any special structure.

The latticework shows similarity to that of the Devonian species of *Dictyophytra*. The skeleton, however, not being better known in these, than in the present species, the generic determination remains doubtful.
Horizon and locality: Upper Utica shale, Holland Patent, Oneida county.

Remarks. Rauff proposed the term Dictyophytra as a modification of Hall’s generic term Dictyophyton. Hall and Clarke (1898, p. 50) doubt that this species belongs to the Devonian genus Dictyophyton, and since they have shown (ibid. p. 39) that the skeletal bands of the Dictyospongidae consist of bundles of diacts, while Rauff’s excellent figure shows the bands of the present species to be composed of stauractins, it is much more probable that the specimen represents a very coarse meshed Cyathodictya. Indeed, Bassler (1915, p. 319) has provisionally placed the species under that genus. Considering the absence of traces of the paragastric invaginations or aureoles, it is, however, possible that the form is nearer related to Palaeosaccus Hinde (1893, p. 56), a similar coarse meshed hexactinellid from the lowest Ordovician of Quebec. In this, according to Hinde, the bands are composed of both slender rhabds and stauractins, but there is no trace of intermediate bands as in Cyathodictya and the present species.

Figures 4, 4a Cyathodictya (q) pyriformis nov. Figure 4, the holotype x \( \frac{3}{4} \); figure 4a, Spicules x 5.

Cyathodictya (?) pyriformis nov.

Text figures 4 and 4a.

Description. Sponge of medium size (holotype 105 mm long and 47 mm wide) inversely pear-shaped; fairly rapidly expanding
from the rounded base to the average width which is attained at one-third of the length, thence more gradually to the last third of its length, whence it contracts again. Osculum apparently situated at upper end; in the type asymmetric on one side. Skeleton consisting of stauractins, attaining 2 mm in length and probably having formed a reticulum or latticework, and of a dense felted mass of minute rhabds, attaining a length of 3 mm but mostly much smaller, and probably comprising the dermal layer.

**Horizon and locality.** Upper third of Utica shale (zone of Climacograptus pygmaeus), in Ohisa creek, Newville, N. Y.

**Remarks.** This species is based on one complete specimen and fragments of two others.

Unlike the Holland Patent material, the specimens exhibit for the most part only a densely black fairly thick carbonaceous film with imbedded spicules of a glossy appearance, but rarely pyritized. There has not been found any unmistakable network of spicules, although patches suggesting a very fine reticulum with meshes about .5 mm wide are seen in several places. The reference to Cyathodictya is therefore based only on the general similarity of the form of the sponge to that of the genotype, though our species still differs from the latter in the less distinct cylindrical shape of the mature portion. Nor has there any evidence been found of the aureoles or paragastric invaginations of *C. reticulata*, and from this negative character and the appearance of the felted mass of rhabds it is also possible that this species belongs to or near Teganium.

Genera *Sphaerodictya* Hall and Clarke and *Teganium* Rauff Walcott (1879, p. 19) described as *Cyathophycus sub-sphaericus* "hollow membraneous fronds with a subcircular opening at the apex of a nearly hemispheric body." These had been observed in the Utica shale of the town of Trenton, Oneida county, N. Y.

In his monumental "Palaeospongologie," Rauff (1893, p. 256) has erected the genus Teganium for *Cyathophycus sub-sphaericus*, describing it as "spherical to oval, or having the shape of a semioval crucible; with broad, rounded base and truncated, somewhat contracted and rounded off upper margin, which surrounds a large osculum." The wall is considered as very thin and the pyritized, wholly compressed body showed only traces of minute stauractin spicules. Drawings of a crucible-shaped specimen, nearly 2½ inches high and wide, and of several supposed young are furnished.
Hall and Clarke, in the memoir on the Dictyospongidae (1898, p. 25) have pointed out that the characters ascribed to Teganium fail to apply to the spheroidal sponges which Walcott had before him when he described his *Cyathophycus subsphaericus* and therefore proposed a new genus Sphaerodictya for the disk-shaped fossil, at the same time fully describing and figuring the structure of its skeleton.

Finally, Bassler in the important Bibliographic Index of American Ordovician and Silurian Fossils, volume 2, 1915, page 1259, has placed Sphaerodictya as a synonym under Teganium.

Sponges which the writer has collected at Marcy and about Dolgeville seem to throw light on the difficulties created by the partly contradictory descriptions of the “*Cyathophycus subsphaericus*” by Rauff on one hand, and Hall and Clarke on the other, which have led to the apparent erection of two genera for the same species. The fact is that there are actually two different forms involved, a disklike, originally sphaeroidal type, the true subsphaericus and genotype of Sphaerodictya Hall and Clarke; and a cuplike form, a new species which corresponds to Rauff’s generic diagnosis of Teganium.

This latter will be properly called *Teganium subsphaericum* Rauff. We have further before us a series of specimens representing a new species of Teganium from the uppermost Canajoharie beds at Dolgeville, N. Y., here described as *Teganium rauffii* and a third species, *T. macrosciera* from the upper Utica at Holland Patent. These additional species indicate that the parietal skeleton, consisting of the lattice-work of spicules, is exceptionally fine, as was suggested by Rauff for the genotype.

*Sphaerodictya subsphaerica* (Walcott)

Plate 3, figures 9-11

*Sphaerodictya subsphaerica* has been fully described by Hall and Clarke in a publication of the State Museum, to which we refer the reader (1898, p. 766).

It appears from this description and the excellent figures, that the sponge was most probably spherical in shape, and possessed a thick wall which, however, in no case has shown an aperture. The specimens are, as a rule, so split that the inner surface of the wall is seen which exhibits a great number of mural openings. The wall consists mainly of short rodlike spicules, but also a thin
lamina of stauractin spicules making a regular quadrate mesh has been seen. The entire outer surface is armed with short, erect spicules.

We were fortunate enough to collect at Marcy a specimen which is more favorably preserved than those which Hall and Clarke had before them. From this we can add the following data.

The wall is here so preserved that it is seen that the mural pores on the inside of the wall are the interior openings of canals that lead without contraction to the outside (see plate 3, figure 9). The diameter of these canals is 1.5 mm on the average. Between them are seen regularly distributed pores only .5 mm or less in diameter, both on the inside and outside of the wall (the latter shown near the left margin of the specimen) and hence corresponding to a system of finer canals between the wider ones.

Considering the absence of any large osculum leading to a paragaster and the fact of the opening of both the wide and narrow canals on the inside of the wall into the wide central cavity — that

Figure 5a Sphaerodictya subsphaerica (Walcott). Restoration of original section, showing canal system.
Figure 5b Oscarella. Diagram showing inhalent canal system (a) and exhalent canal system (b). (After Parker and Haswell).

in the compressed fossils is occupied by a thin lenticular body of shale — we are led to the conclusion that this sponge was of com-

1A single specimen in the United States National Museum, out of several hundred which I have before me, shows a broad opening of the wall on one side, which might be claimed as suggesting a large osculum. The absence of a corresponding feature in the other specimens leaves, however, no doubt that this is an accidental opening or a flattened base of attachment.
plex structure, lacking the common paragastric cavity but possessing numerous exhalent canals, the larger ones, whose oscula are scattered over the surface, and equally or more numerous narrower inhalent canals, whose ostia are distributed between the oscula. Both sets of canals open freely into the inner cavity. It is therefore to be assumed that this was originally occupied by softer tissue which contained the flagellate chambers, through which the water passed from the inhalent canals to the wider exhalent ones (see restoration, plate 3, figure 11, text figure 5a), as in the recent more complex sponges of the Oscarella type. (See text, figure 5b.)

**Teganium subsphaericum** Rauff

Plate 3, figures 1 and 2; text figures 6-11

As "**Teganium subsphaericum** (Walcott) Rff," this species has been well described by Rauff as follows (translated from Rauff p. 256.)

Sphaerical to ovoid, or having the shape of a semi-ovoid crucible, with broad, rounded base and truncated, somewhat contracted, rounded upper margin, which surrounds a large osculum. This seems to be relatively wider in older individuals, than in the young. Paragaster probably sac-shaped, having the shape of the outline of the sponge. Wall therefore thin; however, apparently not as delicate as in the wide-meshed Protospongidae. The smallest of eight flattened specimens is $3\frac{1}{2}$ mm high and 3 mm wide; the largest about 60 mm high and wide. The osculum is 1 mm in the former and 35-40 mm in the latter.

Of the skeleton, Rauff could observe only traces and he believes that the walls consisted of a thick, extremely fine-meshed network. He was, however, unable to recognize any network and could find nothing but a few, very small stauractins.

Rauff figured one large and three small specimens from the basal Utica at Holland Patent, N. Y. The originals of these figures are in the National Museum; they were, upon Doctor Clarke's request, studied by Professor Charles Schuchert, who inferred that the apertures in both the smaller and also the larger specimens were drawn in.

This is, however, not so, as we could convince ourselves from a study of Rauff’s types. There is a large number of specimens in the United States National Museum, which clearly show the circular apertures. The difference in the much flattened specimens is one of intensity of gloss; the apertures lacking the gloss more or less, because only one wall layer is there compressed into a carbonaceous film.
Figures 6, 7 *Teganium subsphaericum* Rauff.
Originals of Rauff's figure (pl. 4, fig. 3). Natural size.
A reexamination of the type material shows that the small specimens figured by Rauff are young examples of *Sphaerodictya subspaherica*, while the larger figure (plate 4, figure 4) is a combination drawing of two specimens. These latter differ from *Sphaerodictya subspaherica* in their much larger size.

Figures 8–11 *Teganium subspahericum* Rauff.
Figures 8, 9 Specimens identified in U. S. N. Mus. as *Discophyllum typicale* Walcott. x 3. Fig. 10, 11. Wall skeleton and ostia from different portions of the original of fig. 8. x 7.5.

distinct large oscula, and the absence of any traces of the numerous ostia seen in the other species, as well as of the corona of large projecting dermalia. One of the specimens is distinctly oval in shape, instead of sphaerical, and has the aperture at the narrower extremity. A comparison of these two types of Rauff's species with a large series of mature specimens of *Sphaerodictya*
subsphaerica (Walcott) Hall and Clarke, leaves no doubt in our mind, that they represent a different species which should be recognized even though their skeleton is not preserved and therefore can not be compared with that of the second species.

Walcott's type specimen was not accessible to us; it is, however, apparent from Walcott's figure that he had the species described by Hall and Clarke before him, and that Rauff's species is therefore to be regarded as new, although he also was under the impression of studying Walcott's species.

Having failed to discern the wall skeleton, Rauff had already suggested that it consisted of an extremely fine meshwork. One specimen in the National Museum (no. 400, see text figure 10) indeed retains beautifully the wall structure. The meshwork in the interior consists of such delicate spicules, that they seem under the lens to be in contact and sixteen are counted in the space of 1 mm; nearer the margin the meshes are coarser and six or seven of them are counted in 1 mm.

This extreme fineness explains why the skeleton is rarely preserved and the sponge appears entirely smooth. One can, however, also find in the apparently smooth specimens (as the original of text figure 9), patches which show the molds of the extremely minute spicules, and always a few scattered dermalia.

Figure 12 Teganium macrosclera nov. Spicules and portion of wall skeleton. x 3 1/2.

Teganium macrosclera nov.

Text figure 12

Description. Sponge probably broadly bowl-shaped, about 40 mm wide and 25 mm high. Parietal skeleton an extremely fine meshed latticework, about five meshes in 2 mm. Dermal skeleton
containing very large spicules, (prostalia pleuralia and dermalia),
reaching a length of 18 mm and a width of .3 mm; some of the
spicules distinct hexacts, others apparently hexacts and some mo-
nacts.

**Horizon and locality.** Upper Utica shale at Holland Patent, N. Y.

**Remarks.** The distinctive character of this sponge, which is
represented by a single specimen, consists in the extremely large
size of the dermal spicules, which strongly contrasts with that of
the other species of Teganium, as well as that of the associated
*Cyathodictya reticulata*; while the parietal skeleton
is of the same extremely fine meshed and thin character as in the
congener and therefore seen only with difficulty and in small
patches. Also this character finds its counterpart as well in later
Lyssakina as in the Devonian *Actinodictya*, and in recent forms, as
in *Taegeria pulchra* (see Challenger Report, plate VII). As
in these later sponges, the large monacts were probably of the char-
acter of dermalia, lying flat in the epidermal tissue instead of project-
ing above the surface of the sponge in the manner of prostalia. It
will be noted that in the compressed type specimen these large spi-
cules have all an oblique upward direction, which is also the case in
the later sponges, here cited, where they form two intersecting
systems, somewhat suggested in *T. macrosclera* (see text
figure 12.)

**Teganium rauffi** nov.

Plate 1, figures 3-5

The writer has collected in the uppermost Canajoharie beds at
Dolgeville, N. Y., a number of sponges which, so far as known,
also belong to Teganium and which may be described in this con-
nection.

**Description.** Sponge of variable shape, semi-oval to sac-shaped,
with a flat upper side and large osculum. Specimens attain a size
of 45 x 50 mm with an osculum about 1/3 the width of the
sponge.

Of the spicules we have seen only a few stauractins and
groups of simple rods, as indicated in the figures. One specimen
retains only the fine hairlike depressions where the spicules had
lain, thus indicating how the skeleton, like all calcareous and sili-
ceous shells in the fine, argillaceous Utica mud shale, have en-
tirely disappeared by solution.

From the extreme compression of the bodies and the faintness
of the carbonaceous film they have left, it is obvious that the wall of the sponge was extremely thin and the paragastral cavity large.

It is also probable, that they possessed only a very delicate skeleton of small spicules. The rods are about 1–1.2 mm long in the average.

**Horizon and locality.** Upper Canajoharie shale at Dolgeville, N. Y.

**Remarks.** This species is principally distinguished from the genotype by its more variable, and in general, more elongate form. It also occurs in another faunal association.
Family *Foerstellidae* nov.

*Foerstella* gen. nov.

*Foerstella* represents a group of hexactinellid sponges that are characterized by bundles of long straight spicules protecting and supporting the walls of the paragastric cavities. These spicules are of the character of smooth oxydiacts and these sponges represent the first development of a distinct gastric skeleton in the Paleozoic hexactinellid sponges.

The dermal and parietal skeleton appears to have been thin and to have consisted of uncemented minute hexacts (?), pentacts, tetracts and monacts or diacts. In one species (*F. rotunda*) these spicules were seen to arrange themselves into a regular meshwork of apparently uncemented skeletal elements and the dermal and parietal skeleton is therefore believed to have been of the primitive type of the Lyssakina.

The sponges referred to here were composite, several paragastric cavities being observable in each of them. In the genotype, *F. rotunda*, the 6 or 7 large paragastric cavities are seen to radiate from the central portion of the sponge in various directions toward the surface and to overlap in such a way that they could not have been disposed in one plane.

The entirely smooth surface of the completely flattened sponges gives no indication of the former presence of ostia or inhalent canals. It is, however, possible that the short marginal canals along the upper left margin are the remains of inhalent canals; and that all trace of these in the remainder of the sponge has been destroyed in the collapse of the skeleton and the flattening of the body.

No basal tufts have been observed.

It is quite obvious that the characters of these hexactinellid sponges preclude their reference to the Protospongidae which comprise the lyssakine hexactinellids from the Cambrian shales, or the Plectospongidae, a family erected by Rauff for Cyathodictya, with which our species are associated at Holland Patent, nor finally to the Dictyospongidae which attain such a profuse development in our Devonian. All of these lack on one hand the strong gastric skeleton of *Foerstella* and possess on the other a parietal skeleton that is distinctly latticed.

It gives me great satisfaction to be able to name these remarkable sponges after Dr August F. Foerste, an indefatigable and most successful student of the lower Paleozoic faunas and formations of North America.
There are, however, recent Hexactinellida known which possess an identical gastral skeleton of long monaxone spicules. Such a form, well illustrated in the Challenger Report is *Polylophus philippinensis* Gray, a member of the small family Rossellidae. It is possible that Foerstella is also referable to this family of deep sea lyssakine Hexactinellida, for the most characteristic feature of the Rossellidae, namely, the absence of any distal ray in the dermal spicules, is also suggested for our genus by the smooth outline of the sponges. On the other hand, Foerstella is a group of composite sponges and the Rossellidae are simple sponges. As a matter of fact, there are, to our knowledge, no composite Lyssakina, although there are forms with numerous oscula known among the Dictyonina. It would, for this reason, produce confusion if one united these strangely divergent forms with the Rossellidae. Their proper place is in a distinct family for which we propose the name Foerstellidae, a family of Lyssakina that is to contain composite sponges with strongly developed bundles of gastralia, the latter consisting of long straight or slightly curved or twisted rhabds, probably of the nature of diacts.

**Genotype. Foerstella rotunda.**

**Foerstella rotunda** nov.

Plate 2, figures 1 and 2

**Description.** Sponge of large size (height and width about 130 mm), squarish with rounded corners in outline, originally probably globose to rounded cubical. Seven or more paragastric cavities, of uniform width, about 10 mm wide, and extending half the diameter of the sponge, radiating in all directions. Oscula circular, of the diameter of the paragastric cavities, situated in depressions. Inhalent canals (?) small, about 1 mm wide.

Gastralia long (about 70 mm) straight or slightly curved, stout rhabds, .35 mm wide (in pyritized condition). Parietal skeleton (or dermal skeleton [?]) forming a tissue of extremely delicate spicules, mostly monacts (or diacts), but also spicules which now appear mostly as tetracts but originally may have been pentacts or hexacts; the rhabds arranged in two dominant directions, rectangular upon each other, thus suggesting the presence of an imperfect lattice structure. No projecting rays of dermalia are seen along the margin,

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1 Report of the Scientific Results of the Voyage of H. M. S. Challenger, etc. Zoology, v. 21, 1887, pl. 53, fig. 1.
nor are the oscula protected by projecting prostalia marginalia. Nor has there any basal tuft been observed.

**Horizon and locality.** Upper Utica at Holland Patent, N. Y.

**Foerstella flabellata** nov.

*Plate 3, figures 3-8.*

**Description.** Sponge of medium to large size, of clavate shape; expanding first rapidly from the base, then very gradually to the truncated top. Entire sponge perforated by numerous, subparallel paragastric canals, that beginning in the lower part extend upward and empty on the flat top. These canals are about 1.5 mm wide, extending distally to about 2.5 mm, which is the width of the oscula. The paragastric walls are furnished with bundles of fine, closely arranged rhabds, most of which apparently reach the full length of the canal. The wall consists of a confused mass of densely crowded, irregularly scattered spicules, mostly rhabds, with few extremely minute tetractins or pentactins. The margin of the sponge is entirely smooth, as are also those of the oscula. Basalia have not been observed.
Horizon and locality. Upper Utica shale (zone of Climacograptus pygmaeus) at Holland Patent, Oneida county, N. Y.

Remarks. We doubt that without the single type specimen, we would have recognized the sponge nature of this species, for the other specimens here figured had already been described as belonging to the alga Sphenophycus. This single specimen, however, shows distinctly the pyritized paragastric canals with their surrounding rhabds of gastralia. The transition from these to the specimens in which all traces of the substance of the paragastric canals and the spicules of the wall have been destroyed by solution (see text figure 16) is furnished by the specimen reproduced in plate 3, figure 4, in which the substance of the canals, except a small spot at the right edge, is already transformed into alum. After this is dissolved the fairly smooth carbonaceous patches are left, that suggest algal remains. But careful search, even in these cases, brings out the presence of scattered sponge spicules or even small patches of connected tissue.

This species is at once distinguished from the genotype by the much smaller size of the paragastric canals and their different arrangement.

Genus Polyplectella nov.

Polyplectella mira nov.

Plate 8, figure 2; text figure 18

The National Museum contains two specimens of a fossil from the Frankfort shale, “three miles north of Rome,” (Six Mile creek), that represent a sponge of decidedly new habitus and for this reason have been made the types of a new genus and species.

The distinguishing character of the genus consists in the support of the body of the sponge by numerous basal tufts, if we conceive the fossil correctly. While there are good examples of such sponges known among the recent Hexactinellida, as, for example, in Polylophus and Pheronema (see Schulze, 1887), we are not aware of a similar occurrence among Paleozoic forms. Separate basal tufts of Lyssakina have long been known from the Cambrian and Ordovician and united under the term Pyritonema McCoy, and Dawson has also described species of Protospongia with simple basal tufts, consisting of only a few spicules.

In Polyplectella the sponge body which is cylindrical, and possesses a large paragaster, gives off, from its entire exterior surface, bundles of spicules that distally spread out brushlike and apparently served to support the sponge or rather to prevent it from sinking.
into the soft mud. Polylophus philippinensis Gray (Schulze, 1887, pl. 54, fig. 1), in a like fashion, produces tufts of spicules all over its surface which bend downward and often unite

into a single mass of spicules at the base, while in Pheronema annae Leidy (ibid. pl. 42, fig. 1) ten or more tufts proceed downward from the basal surface of the sponge.

In the smaller of the two specimens the body of the sponge is 8.3 mm long and uniformly 2 mm wide. Its basal extremity is rounded, the distal one, which is obliquely compressed, exhibits a wide circular osculum (diameter 1 mm). There are sixteen basal tufts observable now, but more were undoubtedly present originally. Most of these originate in the basal portion of the sponge, but three proceed from points within 2 mm of the osculum. The tufts are in the type specimen which is not a full-grown individual about 12 mm long and expand from an initial width of .5 mm to as much as 3 mm.

In the second specimen the sponge body is apparently compressed in a vertical direction and a confused radiating mass of basal tufts
results. These number about thirty; they reach a length of 25 mm and a distal width of 4 mm.

The basal tufts are flexible to some degree; they consist of slender spicules, which in most cases, through gradual compression suffered by the fossil, have been arranged into wedgeshaped bands, that appear, under the lens, uniformly striated, the spicules being in contact. In this condition sixteen are counted in the space of 1 mm. Under the microscope it is seen that the spicules are pressed in some places irregularly into and upon each other; and also that the finely granulose surface of the spicules is due to their composition of pyrite granules; the pyrite having in the Frankfort shale at Six Mile creek replaced most delicate structures which thus have been preserved as neatly as the famous appendages of Triarthrus and Cryptolithus from this locality.

Anchorlike terminations have not been discerned attached to the basalia, but minute four-rayed spicules which lie at the extremities of the basalia in the larger specimens, may well represent the anchoring portion of the spicules which then were pentactins originally.

The sponge body, under the lens, shows a rough, nodular surface, with numerous openings in the lower part, which suggest ostia surrounded by thin sponge tissue. Viewed under water, minute four-rayed spicules are seen, probably hexactins or pentactins and apparently of the nature of dermalia, and in the lower portion a confused mass of twisted fiberlike spicules, which undoubtedly are basalia. Three of the four-rayed spicules were observed arranged in parallel direction; they may therefore be elements of the parietal wall (parenchymalia). In this case, the skeletal elements were not connected and the form was a true member of the suborder Lyssakina of the Hexactinellida; and probably of the family Protospongidae Hinde.

Genus *Sycodictya* nov.¹

*Sycodictya rara* gen. nov. et sp. nov.

Plate 4, figure 5

Description. Sponge of small to medium size, sac-shaped, with thick wall, small osculum at the upper extremity and a wide paragaster, which rapidly expands below the osculum and in the lower half gradually contracts towards the proximal end. Walls perforated by numerous canals which do not extend from the exterior

¹ Etymology σκόκος a fig, in allusion to form, and δικτός a net.
to the interior surface but are mostly noticeable in the inner part of the wall. Skeleton composed of uncemented spicules, apparently monactins (derived from hexactins) arranged in interesting radiating and concentric systems; the radiating so spaced that four to five are counted in the space of 1 mm, the concentric ones more irregularly distributed. The canals apparently surrounded by thicker spicules. The dermalia consist, judging from a very small number observed, of thin, long (as long as 4 mm) tetractins.

Figures 19, 19a *Sycodictya rara* nov. Figure 19 Extremity of canal and wall skeleton, x 14. Figure 19a Dermalia x 7.

Figure 20 *Pyritonema rigidum* nov. Bundles of spicules x 5.

**Measurements.** The type measures in length 80 mm, but is broken at the base, and originally was about 100 mm long. Its greatest width at about one-fourth of its length from the distal extremity, is 53 mm. The osculum is 8 mm wide, the paragaster 18 mm at its greatest expansion and 3 mm at the lowest end, where broken. The thickness of the wall would seem to have varied from 10 to 20 mm, and the canals are 1 mm wide.

**Horizon and locality.** Upper Utica shale (zone of Climacograptus pygmaeus). Holland Patent, Oneida county, N. Y.

**Remarks.** Both this genus and species are based on a single specimen, which however, is so well preserved and exhibits such dis-
tinctive characters that its description as a holotype of a new form seems fully warranted.

The form is principally interesting for the combination of a lyssakine hexactinellid structure of the skeleton with thick walls perforated by a distinct system of canals. It will be remembered that the Hexactinellida among the sponges are distinguished by their thin walls with indistinct canals. It seems further that the canals, apparently exhalent canals, were protected by thicker spicules, with thickened ends (see text figure 19). In this case it is possible that we have here before us a further development of the type of sponge described in Foerstella, namely, a thick walled form with numerous paragasters, protected by gastralialia, but which has developed, as a further complication, a common cavity.

On account of the thick walls and the apparent presence of thick gastralialia around the canals we have, provisionally associated this form with Foerstella.

The generic characters of Sycodictya are to be seen in the combination of the lyssakine structure, with the thick walls, a distinct system of canals and a wide paragaster.

Family Hyalonematidae
Genus Pyritonema McCoy

The upper Utica shale at Holland Patent which has afforded the finest sponge fauna of the Cincinnatian, contains also separate bundles sometimes composed of hairlike flexuous filaments, or their impressions, and sometimes of rigid rhabdlike bodies. Similar bundles have often before been observed in other Paleozoic strata. They have been described by Walcott (1886, p. 89) from the Lower Cambrian of Vermont as Leptomitus, and by others from the Ordovician of Europe and Canada, as well as the Carboniferous as Pyritonema and Hyalostelia.

Rauff, in his Palacospongologie (1803, p. 257 ff.) has furnished a very elaborate discussion of Pyritonema and arrived at the conclusion that it represents the basal tufts of various genera of Hyalonematidae. He proposed to use both terms, Pyritonema McCoy and Hyalostelia Zittel, as conventional means of identification, but to reserve Pyritonema McCoy for the earlier Paleozoic forms and Hyalostelia for the later ones. He recognizes species from the Tremadoc and Llandeilo of Britain (P. fasciculus), from the black shale of Little Metis bay in Quebec and from the Ordovician of Scandinavia; found in boulders in Germany. Leptomitus
Walcott from the Georgian of Vermont is considered as referable with doubt to the sponges. Walcott's statement that a "confused mass of spiculae (?)" occurs at the larger end, is in our opinion, evidence that this form is also a Cambrian Pyritonema.

**Pyritonema capilliforme** nov.

Plate 4, figures 6 and 7

The bundles before us show in two cases the pyritized spicules or parts of them, in the others only the impressions, the pyrite having been oxidized and dissolved. There are two different forms discernible, the one very flexible and composed of extremely delicate numerous fibers, the others straight and rigid, and composed of fewer and thicker rhabds. The former have about twenty rhabds in the space of 1 mm, the latter not quite ten. As, however, there occur wide variations in the relative length and thickness of the tufts and the composing basalia in the same species of Hyalonematidae, it is not advisable to distinguish the two forms.

The length of the bundles is from 50 to 65 mm, the width increases from 2 mm to 3.5 mm in the narrowest specimen, and from 1 to 6 mm in the widest.

There is no sponge known from the Utica shale which possesses a long basal tuft. On the other hand, the sponges here described as species of Foerstella possess bundles or rings of rhabds in the paragastric walls that are similar to the more rigid bundles here referred to Pyritonema. We therefore consider it quite possible that these bundles of rhabds are the last remains of Foerstellas that have been macerated to such a degree that only the strong paragastric spicules have survived. This is true especially of the rigid rhabds; while the bundles of extremely fine fibers are more suggestive of the basal tufts of hexactinellid sponges.

**Horizon and locality.** Upper Utica shale at Holland Patent, N. Y.

**Pyritonema rigidum** nov.

Plate 4, figure 8, and text figure 20

We will, in this connection, also describe a type of Pyritonema that does not properly belong in the faunal associations here dealt with. It was observed in the Normanskill shale of Mount Moreno near Hudson, N. Y., 25 years ago, but hitherto was not recognized in its true nature and thus left out of the fossil lists.

The bundle is 48 mm long, widens from 5 mm at one extremity
to 8 mm at the other, and is of extremely rigid appearance. Seen with the naked eye it shows only 8 and 9 widely separated, perfectly straight, strong, rhabdlike bodies about .5 mm wide. A lens dissolves these, which are smooth and compact in most parts, into bundles of much finer fibers and shows also such finer rhabds in the interspaces between the coarser ones. A partly carbonaceous film surrounds and binds the bundles.

From the rigid character of this bundle, the fact that it is of a composite nature, the apparent rhabds being bundles of finer spicules, and the presence of a carbonaceous film, we incline to the view that it more probably represents the wall structure of a paragastric cavity than a basal tuft. The composition of the larger bundle or skeletal tube of bundles of finer rhabds finds its counterpart in recent Lyssakina where strands are bound together by siliceous cement, as, for example, in Taegeria (see Challenger Report, Hexactinellidae, plate 8) and then present an appearance identical to that here seen in Pyritonema rigidum. The cementing of the rhabds of the finer bundles would also explain the smooth surface of portions of these bundles (see text figure 20).

**Incertae sedis**

**Genus Clionolithes** Clarke

**Clionolithes quaerens** nov.

**Text figure 21**

In the black shale of the lower Whetstone gulf formation in the Wood creek section (station 1) and at other places about Rome, beautifully preserved exterior casts of cephalopods occur, in which the shell substance has been entirely dissolved but every detail of sculpture preserved and impressed upon the shale. These sculpture casts sometimes exhibit mud-filled borings of such a peculiar character as to invite more attention than as a rule is given to borings in shells.

Doctor Clarke in his suggestive paper on the Beginnings of Dependent Life (1908, p. 146) has given a new aspect to these neglected shell borings and shown their importance for the philosophy and development of parasitism. This fact and the remarkable nature of the borings before us have invited their description.

The borings are straight, not more than .5 mm wide and following the longitudinal direction of the conch. The growth lines of the conch pass over them in such a way as to prove that they were
either within the shell substance or on the inner surface. Wherever they strike a septum, they end abruptly and a side branch takes up the old direction. In the first specimen here figured, at one septum the boring divides with five or more forward radiating branches, some of which are excessively thin, but one of which is about half the width of the other boring. In this and other specimens similar thin borings branch off the main channel at irregular intervals. These thin borings gain again in width as they continue. In an unfigured specimen, the boring disappears entirely at one septum, and reappears in the next air chamber with three thinner borings a considerable distance from the older one.

It appears that the boring organism followed the shell closely to its inner surface until it reached a new air chamber, for the bor-

Figure 21 Clionolithes quaerens nov. Holotype x 3.
ings do not disappear exactly at the septum, but just a little beyond it. Then it branched out into the newly gained air chamber probably living in the organic matter still present there. Meanwhile a branch as thick as the old stem followed the inner shell surface until it reached the next air chamber. From the direction of the boring, which is not irregular but follows the growth of the conch, it would seem that the organism attacked the air chambers of the living shell as they were abandoned by the cephalopod; and from the mode in which the stem of the boring is able to break up into minute channels, it would follow that the organism could hardly have been a boring worm but rather a boring sponge or alga, most likely the latter; for it is now known that in the breaking down of shells, corals and other calcareous bodies in the sea the algae play by far the predominant role. We have united this form with Clionolithes Clarke although the latter name is intended, as it implies, for boring sponges. It will still be time to apply a new name to this form, when the true agent of these borings has become known.

Family Receptaculitidae

Genus Ischadites Murchison

Ischadites circularis (Emmons)

Emmons (1855, p. 230) has described, as Receptaculites circularis, a problematic fossil from the "Lorraine shales" (locality not given), as follows:

This coral is in the form of a thick, flattened ring, studded with circular cells, arranged in regular lines traversing it rather obliquely. It belongs to the Lorraine shales.

Winchell and Schuchert (1895, p. 65), in their Synopsis of American species of Ischadites have referred the Lorraine fossil to that genus, remarking that it may be identical with I. iowensis, but that the spicular head plates seem to be larger. I. iowensis is an earlier (Galena) form, with more closely arranged spicules.

No other specimen has been obtained and the whereabouts of Emmons's type is unknown to the writer. The latter seems to have been a view of the basal side of a natural cast of the space left between the vertical rays of the spicules, the imbricating head plates of the spicules having been lost. The find is mainly interesting as indicating the presence in our Lorraine formation of the peculiar and problematic genus Ischadites of the Receptaculitidae.
Class Anthozoa
Subclass Tetracoralla
Family Cyathophyllidae
Genus Columnaria Goldfuss

**Columnaria alveolata** (Goldfuss)

Hall (1847, p. 275) has described and figured as *Favistella stellata* a tabulate coral from the “Hudson river group” of New York, stating that this species is scarcely known in New York, a few obscure specimens being all that has been observed in the shaly parts of the Hudson river group; while the form is abundant in the West.

Emmons (1855, p. 229) has again briefly described and figured the same coral under Hall’s name as occurring in the Lorraine shales.

Milne-Edwards and Haime (1851, p. 309) made *Favistella stellata* a synonym of *Columnaria alveolata* Goldfuss; and were later corroborated in this view by Nicholson (1875, p. 23.) Goldfuss (1826, p. 72) described his species from material said to have come from the shores of Seneca lake and hence probably derived from the drift. In 1879 Nicholson (1879, p. 200) pointed out that while Hall’s *Favistella stellata* is identical with *Columnaria alveolata* Goldfuss; the Black river limestone form, on the other hand, identified by Hall with Goldfuss’s species is distinct and should receive a new name, for which he proposed *Columnaria (?) halli*.

The occurrence of the *Columnaria alveolata* which is common in the Cincinnatian and now known to range from the Stones River to the Richmond, in our Lorraine, is mainly interesting in pointing, by the extreme rarity and poor preservation of the specimens, of this single known coral from our Lorraine beds, to the unfavorable condition then prevailing here for the growth of corals.

Class Graptolitoidea

Order Dendroidea

Family Dendrograptidae

Genus Dictyonema Hall

**Dictyonema arbusculum** (Ulrich)

*Dictyonema arbusculum* became first known from the middle Eden of Covington, Ky. (Ulrich, 1879, p. 28). It has been described and figured in the Graptolites of New York, pt 2, p. 152;
and having been found in the Indian Ladder beds of New York, it has again been figured by Ruedemann in New York State Museum Bulletin 162, p. 77. The species has not been observed again in this State.

**Genus Callograptus Hall**

**Callograptus compactus** (Walcott)

Plate 5, figures 2-4

*Callograptus compactus* was originally described as *Dendrograptus compactus* (Walcott, 1883, p. 21). It has been redescribed and refigured by Ruedemann in Memoir 11, Graptolites of New York, p. 146, where it is referred to *Callograptus*. It has been found only at Holland Patent and South Trenton in the lower beds of the third Utica division; there in sufficient number, however, to make it a characteristic fossil of the subhorizon carrying the fauna of graptolites and sponges that became first known from Holland Patent.

![Figures 22-24](image)

**Figures 22-24 Callograptus compactus** (Walcott). Enlargements (x 11) of branches, showing projecting thecae. No. 34463, United States National Museum.

The thecal apertures have been described as simple circular pores in the genotype, *C. salteri* (Ruedemann, 1904, p. 584) and in *C. compactus* (1908, p. 146) as but very slightly projecting. A specimen of the latter species in the United States National Museum retains however several branches turned sideways and these show long, projecting, tubular, distal parts of the thecae arranged in close series on one side of the branches. The circular pores
seen in the other branches are then obviously but sections of the broken-off thecae. That also the genotype possessed this structure of the rhabdosome, is indicated by a figure given by the author (1904, p. 585, text figure 18) which shows obliquely compressed, projecting tubular thecae. The importance of this feature was recognized at that time. It shows that the difference between Dictyonema and Callograptus was one of habitus largely, Callograptus being provided with but few of the strengthening transverse supports of the rhabdosome.

It is to be presumed, though not seen in the specimen, that the projecting tubes were composite in nature as in Dictyonema, containing the apertures of the several kinds of thecae, described by Wiman.

Genus Mastigograptus Ruedemann

Mastigograptus simplex (Walcott)

Mastigograptus simplex was described and figured by Walcott (1883, p. 20) as Dendrograptus simplex from the upper Utica shale at Holland Patent, N. Y. It has been more fully described and figured in the Graptolites of New York, (Ruedemann, 1908, p. 218).

Mastigograptus tenuiramosus (Walcott)

Mastigograptus tenuiramosus was first described and figured by Walcott (1883, p. 20) as Dendrograptus tenuiramosus from the upper Utica shale at Holland Patent, N. Y. It has been redescribed and refigured in the Graptolites of New York (Ruedemann 1908, p. 216) where it is made the genotype of Mastigograptus.

This species is also known to occur in the lower Eden at Covington, Ky., and is cited in part 1 from the higher horizons of the Utica, in the Maynard creek and Mill creek sections.

Mastigograptus gracillimus (Lesquereux)

Plate 5, figure 4

This was described by Lesquereux as a land plant from the lower Cincinnati beds at Covington, Ky. (Proc. Amer. Phil. Soc., v. 17, 1877, p. 164) and referred to the graptolites by Walcott (1883, p. 21). It has been more fully described in the Graptolites of New York (Ruedemann, 1908, p. 219), and is there shown to be very closely allied to M. tenuiramosus, which it replaces in the Eden and Maysville formations of the Cincinnati region.
Figure 25  *Mastigograptus gracillimus* (Lesquereux)  
Branch with thecal apertures.  x 11.  1 1/2 miles east of Rome.  (23536, United States National Museum.)

Figures 26-28  *Mastigograptus laevis* (Hall).  Figure 26 Main stem with apertures and thin branches. Natural size. (Deer river shale, Whetstone gulf, N. Y.). Figure 27a two portions of same stem x 7. (Frankfort shale, Six Mile creek, Rome, N. Y., United States National Museum.). Figure 27b Specimen from Frankfort shale at Delta dam, N. Y. x 7. Figure 28 Specimen from Deer River shale, Turin, N. Y. x 7.
An intercalated black band in the Frankfort shale at the Delta dam near Rome, N. Y., has afforded specimens of a Mastigograptus that possess the slender, flexuous habit of the branches of *M. simplex*, shown also to some degree by those of *M. gracilimus*. As in the latter species, the internodes between the bases of branches are slightly expanded, and the internodes are in one set of branches 2.5 mm and in those of the next order 2 mm apart. This Frankfort form would thus seem to be more readily identifiable with the western Eden species than with any of our Utica species. Fragments comparable to this species have also been observed at station 1 of the Wood creek section, in zone 1 (beds of Economy age) and it has been identified by Doctor Ulrich in a collection from the Lower Lorraine shales, 1½ miles east of Rome, N. Y. It likewise occurs in the Whetstone gulf shale in the Totman and Lorraine gulfs.

**Mastigograptus laevis** (Hall)

This species has, owing to imperfection of material, passed under several specific and generic designations. It was first described by Hall (1847, p. 274) as *Graptolithus? laevis*, a fossil from the Utica shale at Turin, N. Y. The type specimen, now in the American Museum of Natural History, is a featureless, flexuous, simple, smooth, carbonaceous band, .8 mm wide and 55 mm long.

The species was later referred by Gurley (1896, p. 89) to his new genus Phycograptus. Ruedemann (1908, p. 244 ff) has shown that the genotype of Gurley's genus, *P. brachymera*, from the Normanskill shale, is the frontal view of branches of Dicellograptus; a fact that invalidates the generic term Phycograptus. In the same publication, Ruedemann thought that *Graptolithus? laevis* might be identical with a similar slender form from the Canajoharie shale, which later (1916, p. 87) has been described by him as *Serpulites gracilis*. Also this view has been proven an error by a lucky find in the shale of the Whetstone gulf, which showed that the flexuous, apparently segmented bands are the main stems of another hitherto very imperfectly known fossil, namely, *Graptolithus arundinaceus* Hall.

In volume 1 of the Paleontology of New York, in which *Graptolithus? laevis* is described, there is also figured (plate 74, figure 8, 8a) as *Graptolithus arundinaceus*, but not described, a small bifurcating branch of a graptolite. The original of this figure is in the American Museum of Natural History, and labeled as coming from the Utica shale at Turin, N. Y.
Graptolithus arundinaceus has been placed by Ruedemann (1916, p. 221) under Mastigograptus, but the question left open whether it may not be identical with the similar M. simplex (Walcott).

It is now certain from material collected by Ruedemann that both Graptolithus? laevis and Gr. arundinaceus represent different parts of the same graptolite-rhabdosome; the first the main stipe, the other a distal portion of a branch.

A comparison of material of Graptolithus laevis and arundinaceus from the type locality, that is, Mill creek near Turin, and also from the neighboring Whetstone gulf, with specimens of Mastigograptus simplex from Holland Patent shows the close similarity in the slender and flexuous branches but also brings out the fact that the main stems are furnished with more closely arranged and larger apertures. While in M. simplex these are about 3 mm apart, they are in this species within 1 mm of each other. Further, while in the former species they appear as circular apertures, they are here most frequently seen as transverse slits. These have been taken for transverse partitions by Doctor Gurley, who states that he has seen in another specimen of Phycograptus laevis "all the essential Phycograptus characters, namely, segmentation, pits, marginal grooves; and, in addition what appeared to be traces of a central chitinous virgulalike thread." We have the specimen in question (now in the United States National Museum) before us; and learn from its inspection that the pits — midway between the apertures, but not regularly alternating with them, but scattered — are the bases of smaller branches, while the faint chitinous virgulalike thread, which passes obliquely upward, is probably a trace of a thecal wall within the common tube.

The appearance of the closely spaced, transverse apertures is extremely misleading, since most specimens are but casts of the interior of the tube, in which the filling of the apertures is seen as apparent partitions, while the central pits would then be taken for the thecal apertures, as was actually done by Gurley. We have, however, found several specimens in the Whetstone gulf retaining the exterior test and in these it is seen that the transverse partitions correspond to apertures that range in the same specimen from circular to narrow transverse, elliptic or even slitlike apertures. (See text figure 27a.)

In several specimens there are seen below some of these larger apertures very small, narrow transverse openings (see text figure
27b) which may have been apertures of a different kind of thecae, such as gonangia.

The essential features of this species would then be, so far as known at present:

Rhabdosome of large size, of flexuous appearance, the slender stems uniformly thick for great distances (about .8 mm thick); the branching monopodial or lateral, apparently rather infrequent. Main stipes bear large apertures, reaching the width of the stipe and circular to transverse elongate in outline; irregularly arranged and numbering about 10 in 10 mm.

**Horizon and locality.** In the Frankfort shale at Six Mile creek and below the Delta dam near Rome, Oneida county; and near Holland Patent; in the Deer river shale at Mill creek, Turin, N. Y. and Whetstone gulf near Martinsburg, N. Y. It has not been observed in the true Utica shale at Holland Patent.

**Genus Corynoides** Nicholson

**Corynoides ultimus** nov.

Plate 5, figure 1

**Description.** Rhabdosome small and slender, about 5 mm long and .6 mm wide; straight, of rigid appearance, or but slightly bent, consisting of a sicula and two thecae. Sicula relatively long (2 mm) and thin. Thecae very slender, of nearly equal width throughout, about 8 times as long as wide, growing in direction of sicula. Apertures of thecae provided each with a triangular or bluntly lanceolate lappet.

This species was found profusely in a few feet of shale in the last division of the Utica shale on Ohisa creek; and is thus separated by a long interval from the species of Corynoides in the Canajoharie shale, which, up to this find, were supposed to represent the last
appearance of the genus in the Ordovician shale on this side of the ocean.

*C. ultimus* is, in its general form, nearest related to and probably a late mutation of *C. gracilis*. It has in common with that species the slender, more or less straight form of the rhabdosome and the very slender thecae, as well as the relatively long sicula. It is, however, but half as long and the apertural spines of *C. gracilis* are developed into lappets.

**Genus Inoaulis Hall**

**Inoaulis arborescens** nov.

Plate 8, figures 3 and 4

**Description.** Rhabdosome arborescent in form; of rather stiff appearance; the branches straight or but slightly curved, dividing

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Figures 34–38 *Inoaulis arborescens* nov. Figures 34–36 Portions of stems showing branching. Natural size. Figure 37 Branch x 5½, showing thecae; further enlargement of latter on right. Figure 38 Extremity of branch with thecae. x 5½.
3 to 4 times (judging from fragmentary material) dichotomously at irregular intervals, forming initial angles of 30° to 50°; of small dimensions (maximum length of largest fragment observed 53 mm), branches of fairly uniform thickness (about 3 mm at base, 2 mm at distal ends). Extremities of branches bluntly rounded. Branches composed of very delicate tubes, that are arranged in parallel fashion and longitudinal direction near the center and curve outward toward the margin where they are nearly perpendicular on the axis or but slightly directed forward. The extremities of the tubes project free, as hairlike projections, irregularly over the general smooth surface of the branch. There are about five of these tubes counted in 1 mm along the margin.

**Horizon and locality.** Frankfort shale at Six Mile creek near Rome, Oneida county, N. Y.

**Remarks.** The fine material of this graptolite in the United States National Museum was labeled as Buthotrephis and indeed the fossil has all the appearance of that Paleozoic “seaweed,” being comparable to such species as B. tenuis and B. ramosa. The tubular structure is so delicate that it is visible only with a strong lens under water, a fact that suggests that also other supposed algae of similar appearance may, with competent material, be recognized as belonging to the graptolites, as happened in the case of *Inocaulis lesqueruexi* (Grote & Pitt), from the Bertie waterlime (Ruedemann, 1916, p. 13).

Moreover, the fact should be emphasized that out of a dozen well-preserved specimens only two retain the extremely delicate tubular structure here described and figured. All these specimens come from the locality near Rome that has furnished the appendages of Trinarthrus and Trinucleus; the preservation of the structure is therefore due only to a most fortunate and infrequent circumstance of preservation. Without this the material would without hesitation have been relegated to the algae and referred to Buthotrephis. One may, therefore, well ask himself how many more of the Ordovician and Silurian “seaweeds” may under favorable modes of preservation be recognized as belonging to the invertebrates.

On account of the stiff appearance, and thinness of the projecting tubes, suggestive of sponge spicules, the possibility that the specimens might be some form of branching sponges has been considered, but the failure to find any paragastric cavities or oscula seems to exclude that alternative view.

The species resembles the genotype, *Inocaulis plumulosus* Hall, from the Niagaran of New York and Canada, and to some
extent also *Buthotrephis ramulosa* Miller, an upper Trenton or Fulton form from the vicinity of Cincinnati, Ohio.

In cases where the filiform extremities of the tubes are lost, smooth, cylindric branches remain which wholly have the aspect of those of *Buthotrephis*.

Fragments, in which bifurcating branches, leave a long main stem under right angles (see text figures 34–36), indicate that the rhabdosome may have reached a much larger size than is indicated by the material, here selected as typical for the species because of the distinction of its graptolitic structure. In these larger fragments a main stem has been developed by the crowding aside of the bifurcating branches on alternating sides; a process also suggested in some of the type specimens of the species.

**Order Graptoloidea**

**Suborder Axonolipa**

**Family Leptograptidae**

**Genus Leptograptus** Lapworth

**Leptograptus annectans** (Walcott)

Plate 6, figures 1–8

Walcott (1883, p. 20) recorded his species *Graptolithus annectans* from the Utica shale at Holland Patent, N. Y. In the Graptolites of New York (Ruedemann, 1908, p. 264) the species is more fully described and figured; and its distribution discussed. It is there shown also to occur in the Utica (Fulton) shale at Cincinnati, Ohio.

A narrower mutation has since (Ruedemann, 1912, p. 31) also been observed in earlier beds, namely, the Canajoharie shale at the lower Mohawk (Crescent, N. Y.).

There occur three distinct varieties of this species in the Upper Utica shale, each of which is found in certain beds in large number and unassociated with the others showing that each predominated at a certain substage of the Utica. Their exact succession has not been made out as yet or the fact established whether they are varieties of one form that meanwhile persisted or are successive mutations. They may therefore be considered at present as varieties.

1. **Leptograptus annectans typus.** This type (plate 6, figure 1) stands in outline between the two other, more
extreme forms. It is characterized by an angle of divergence of 270° to 290°. It is the form described and figured by Walcott and by Ruedemann (1908, p. 264). We have before us a slab about half a square foot in size which bears fifteen specimens exhibiting uniform characters. The branches show a characteristic double curvature in the proximal portion; they attain a length of about 50+ mm, are in the mature portions .8 mm (rarely 1 mm) wide, beginning with a width of .3 mm; the thecae number 10 or 12 in 10 mm.

Upper Utica shale at Holland Patent, N. Y.

2 Leptograptus annectans resupinus nov. This type (see pl. 6, figs. 2-3) is well characterized by the close approach of the resupinate branches, which in their distal parts approach within 40°, forming an axillary angle of 320°; in the proximal portion they diverge at an angle of 220°. The branches lack the double curvature but are concave throughout. They attain a width of 1 mm beginning from a width of .5 mm and the thecae number eight in 10 mm. The branches have therefore a coarser aspect than those of the typical form.

Upper Utica shale. Deerfield near Utica, N. Y.

3 Leptograptus annectans patens. In this variety (see pl. 6, figs. 6-8) the branches diverge widest, the angle measuring 220° to 270° and appear more flexuous and delicate than in the preceding forms. They are .8 mm thick in the mature portion and contain ten thecae in 10 mm there.

Upper Utica shale. Deerfield near Utica, N. Y.

4 Leptograptus annectans amplectens nov. (plate 6, figures 4 and 5). An extreme development leading from the typical L. annectans to a form with semicircular branches which come nearly in contact distally. The branches are slightly wider, beginning with a width of .5 mm and attaining within 30 mm a width of 1 mm, which is maintained throughout the great length (100+ mm) reached by this form.

Upper Utica shale. Holland Patent, N. Y.

There is some variation apparent in the character of the thecae similar to that observed by Elles and Wood in the British varieties of *Leptograptus flaccidus*, where, for example, the variety *macilentus* Lapworth MS. (see Mon. British Graptolites, p. 110), a contemporary form to *Leptograptus annectans*, approaches Dicellograptus by the more pronounced sigmoid curvature of the free outer walls, which is accompanied by the greater introversion of the apertures. The variety *resupin-
inus appears to have least deviated from the typical Leptograptus form of the thecae and the variety patens the most.

Separate branches reaching a length of 70 mm prove that the rhabdosomes attained at times a much greater size than is suggested by the complete specimens at hand.

**Leptograptus flaccidus** (Hall)

*Plate 5, figure 5*

*Leptograptus flaccidus* was first recognized in the Utica shale of Lake St John, Canada, and thence described by Hall (1865, p. 143) as *GraptoTithus flaccidus*.

It has later been found to be a common fossil in the lower Hartfell shales of Scotland, Ireland and Wales (Elles & Wood, 1903, p. 106) in beds approximately contemporary to our Utica shale (zone of Pleurograptus linearis and Dicranogr. clingani). There have further been a number of varieties distinguished in Great Britain. Ruedemann (1908, p. 261) has found mutations of this species occurring already in the Normanskill shale.

![Leptograptus flaccidus](Images)

*Figures 39, 40 Leptograptus flaccidus* (Hall). Figure 39 Proximal portion of var. spinifer Elies and Wood, x 8. Figure 40 Fragment of branch, showing the slightly introverted thecae. x 4³⁄₄. (United States National Museum 54313).

The collection of Utica shale fossils in the United States National Museum from Holland Patent, N. Y., and South Trenton, N. Y., proves that there, in the upper Utica shale, resting directly upon Trenton limestone, *Leptograptus flaccidus* is by no means rare.

Elles & Wood give the following diagnosis of the species:

Stipes narrow, flexed, several cm in length, widening gradually and persistently from their origin to a maximum width of about 1 mm. Sicula 1.5–6 mm in length. Thecae uniformly narrow, ten to eight in 10 mm; inclined at 15°, 7 to 8 times as long as wide, free two-thirds to one-half their length. Apertural margins narrow,
The branches are described as showing characteristically a graceful double curvature in their more proximal parts.

Close to the sicula they are convexly curved with respect to their ventral margins and then bend outward and upward with a concave sweep, running ultimately in an approximately horizontal direction; this curvature is, however, by no means constant in amount.

Typical specimens of *Leptograptus flaccidus* from the Utica (Gloucester) shale of Ottawa, Canada, before us show that this North Atlantic graptolite reached the interior of America through the St Lawrence embayment.

The great length which the flexuous branches of this graptolite attain is shown by figure 5 of plate 5.

Specimens have also been observed at Holland Patent that by the more conspicuous spines of the proximal thecae and longer sicula, suggest the presence of the var. *spinifer* Elles and Wood.

**Genus Pleurograptus** Nicholson

*Pleurograptus linearis* (Carruthers)

The occurrence of this important graptolite of the Hartfell shale of Scotland, in the upper Utica shale at Holland Patent in a single specimen, has been noted in the Graptolites of New York (1908, p. 268), and the form described and figured.

We have nothing to add to the data given there, since no new material has turned up in further collecting.

**Family Dicellograptidae**

*Genus Dicranograptus* Hall

*Dicranograptus nicholsoni* Hopkinson

This species has been fully described and figured by Ruedemann in the Graptolites of New York, pt. 2 (1908, p. 318). It is noted there that the species occurs at South Trenton, Oneida county, N. Y., in black shale of the upper Utica, 6 to 8 inches above the Trenton.

*Dicranograptus nicholsoni* is a widely distributed and long persisting form. It occurs in Great Britain, Scandinavia, Australia and in mutations in Nevada and Arkansas. It appears in mutations as early as in the Chazy (Normanskill) of New York, Nevada and Arkansas and the Trenton (Canajoharie shale) of
New York. The typical form is common in the Snake hill beds of Trenton age in Saratoga county, N. Y. (Ruedemann, 1912, p. 61). It also occurs in the Utica of New York and the Fulton member of the Eden of Ohio. In the middle zone of the Utica shale it becomes so abundant that it characterizes this zone; and specimens have also been found in the Indian Ladder beds (Ruedemann 1912, p. 51) thus extending the range of the species into Southgate time.

At South Trenton the species occurs in great numbers and large individuals in a narrow zone at the very base of the Utica shale there, but 6 to 8 inches above the Trenton limestone. This Utica shale is, however, immediately followed by that of the third zone with Climacograptus pygmaeus. It is therefore to be inferred that here a thin wedge of the northwardly outlapping middle zone is exposed that in the Mohawk valley below Utica is characterized by this graptolite.

Suborder Axonophora

Family Diplograptidae

Genus Diplograptus McCoy

There is probably no more difficult group of graptolites for specific identification, and none apparently less reliable for correlations of strata than the few graptolites of our late Ordovician. The obvious cause of this unsatisfactory character of the material is their small size, the lack of rapid change such as the earlier graptolites show, and instead of this a general approach to a common, indistinct generalized form of these last members of their race.

It thus happens that they have been either identified directly with earlier species, as Diplograptus pristis, foliaceus and amplexicaulis, or Climacograptus typicus and putillus, or have been referred to them and others as late mutations. The following types can be distinguished with some degree of certainty.

Diplograptus amplexicaulis mut. uticanus nov.

Plate 7, figure 1

The single representative species of Diplograptus found in the Utica shale occurs, as a rare form, along Nine Mile creek near Holland Patent, N. Y., in the third division of the formation, close to its contact with the Trenton limestone and at Herkimer.
It appears as a form leading from the Trenton species *amplexicaulis* to the Lorraine species *recurrens*, and is so closely related to the latter that it will suffice to point out their slight differences. Like *D. recurrens*, this form has narrow, slender rhabdosomes of nearly uniform width and of loose appearance, the latter being due to the long straight form, small inclination (30°) and somewhat smaller overlap of the thecae than in most diplograptids. The rhabdosome reaches a length of 35 mm (most rhabdosomes are, however, only one-third that length), and a uniform width of about 2 mm. The thecae number 10 to 12 in the space of 10 mm and are hence a little wider spaced than in *recurrens*. The thecae overlap about one-half their length.

*Diplograptus (Orthograptus) nexus* nov.

Plate 7, figure 5

This small form has been referred by Ruedemann to *D. peosta* Hall in *Graptolites of New York*, pt 2, p. 372; and it is indeed but very little different from that western type.

Since, however, *D. peosta* occurs in the Maquoketa shale of Wisconsin, Minnesota, Iowa and Illinois, and thus is a Richmond or Silurian form, it is obviously misleading to emphasize the similarities instead of recognizing the differences of the two forms in question. There can be but little doubt that both belong to the same group, that of *Diplograptus (Orthograptus) truncatus* Lapworth, a type that is well developed in the uppermost Ordovician of Great Britain (Hartfell shales) and occurs there in a number of varieties. It is apparent that both *Diplograptus peosta* and the form here described as *D. nexus* are only occasional immigrants from the North Atlantic; and comparable to the late mutations *pauperatus* and *socialis* of *D. truncatus*, both occurring in the upper Hartfell shale and thus of very late Ordovician age.

The following are the characters of the species:

Rhabdosome strap-shaped, increasing rapidly at proximal extremity to a width of 1.5 mm; small, attaining a length of 12 mm or slightly more. Section of rhabdosome flat rectangular. Sicula .9 mm in length. The sicular end is rounded, furnished with a short virgella on the sicula and two lateral spines on the first thecae. Thecae 13 to 15 in 10 mm having a length of 2 mm, very straight, of semicircular section, widening somewhat abruptly at the edge of the aperture, overlapping one-half of the total length,
inclined at an angle of 30-40° (?), four times as long as wide. A septum is present, apparently not developed until about six thecae have grown on each side.

This species differs from the very similar *D. peosta* in the somewhat coarser dimensions (greater length and larger thecae) and the less convex section. In their general structure and outline they fully agree and both again have these in common with *D. (Orthograptus) truncatus*, a much larger type, which, however, finally also becomes reduced to the dimensions of the two American depauperated forms.

**Horizon and localities.** Whetstone gulf (Eden) beds at Wood creek, Lees Center near Rome, and in the Lorraine gulf. Foerste records this form (*D. cf peosta*) from the Sheguiandah shale of western Ontario, which corresponds to the middle Eden, and we have seen specimens from the basal Eden in material sent to us by Doctor Foerste from a locality 1 mile east of Fields, Ontario.

**Remarks.** Inasmuch as both *Diplograptus peosta* and *D. nexus*, could be referred as varieties or mutations to the larger group of *D. truncatus*, so well developed in the Upper Ordovician of Europe, and undoubtedly belong to the group of that species, if as widely conceived as the British monographers have done, the question of priority between *D. peosta* and *D. truncatus* arises.

*D. peosta* was described in 1861 by Hall, but not figured until 1895, by Whitfield. *D. truncatus* was described and figured by Lapworth in 1877. *D. peosta* is clearly only a late, small epigone of the larger group that had its metropolis in the Atlantic, and it would be quite misleading to apply its name, on the ground of priority, to the entire group.

In view of the isolated occurrence of these late mutations of *D. truncatus* in the Lorraine and Richmond formations, it is interesting to note that the single diplograptid cited from “beds near the uppermost of the Ordovician” of Peru by Newton is recorded as aff. *Orthograptus truncatus*, suggesting the wide dispersal of this graptolite at the end of Ordovician time.
Figure 41  *Diplograptus nexus* nov. Type x 5. Whetstone Gulf formation, Wood creek, station 1.

Figures 42-46  *Diplograptus recurrens* nov. Rhabdosomes x 5, showing the various expressions partly due to preservation. Figure 43 Type. Original figure 42 from the Lorraine gorge; figure 43 from Lorraine village; figure 44 from Wood creek; figure 45 Lorraine gorge (Allendale); figure 46 Wood creek.
Another troublesome diplograptid of the Lorraine formation has been formerly united by the writer with a species of the Snake hill beds as Diplograptus foliaceus mut. vespertinus (Ruedemann, 1908, p. 352). When it was later found that the type of the latter form came from the Snake Hill beds (Ruedemann, 1912, p. 83), D. vespertinus was restricted to the species from that formation which is of Trenton age. This leaves without a name the form from the Lorraine beds, and which is distinguishable from the Snake hill species.

The long and narrow diplograptid, appearing from time to time in the lower Lorraine (Whetstone gulf) formation, is when preserved in relief, recognizable as a late recurrent form of D. amplexicaulis Hall, our Trenton species; and it has repeatedly been identified with that species (Walcott, 1890, p. 339; Whitfield and Hovey, 1898, p. 20; Ruedemann, 1901, p. 561). When flattened in the shale, its rhabdosome bears through the straight character of the thecae and the imbricating appearance of their proximal portions a striking resemblance to D. nexus and some of the specimens have for that reason been wrongly referred to D. pecta, as, for example, those found in the Indian Ladder beds (Ruedemann, 1912, p. 83). For the same reason the above-cited identifications of Lorraine forms with D. amplexicaulis have been wrongly referred to D. pecta in the Graptolites of New York, pt 2, p. 372.

Diplograptus recurrens can be distinguished from D. nexus when preserved in relief by its plano-convex to concavo-convex section, and when flattened out by the greater length and very gradual widening of the rhabdosome. It may be described as follows:

Rhabdosome narrow, lanceolate, about 20–23 mm long, gradually attaining a width of 1.8 mm from a proximal portion 1 mm wide; concavo-convex or plano-convex in section. Sicula not observed, but a stout, short virgella has been noted. Thecae semicircular in section, long and straight, numbering 13 to 16 in 10 mm; 2.5 mm long, and overlapping one-half of their length, inclined at an angle of 40°. Apertural margin straight and perpendicular to axis of theca. No septum observed.

This species differs from D. amplexicaulis principally in its smaller dimensions (smaller length and width and more closely...
arranged thecae), but would also seem to be more convex on the obverse side.

Hall's figures of *Graptolithus pristis* in Palaeontology of New York, volume 1, are partly referable to this and the preceding species. The specimens reproduced on plate 72, figures 1a, 1b, which come from the "arenaceous slate from the Hudson river group at Turin" belong probably to *D. recurrens*, while that reproduced in figures 1f, 1g, "from the olive slate of the Hudson river group at Lorraine," bears the characteristic features of *D. nexus*, although larger than the specimens at our disposal.

The presence of this species in the Canadian upper Eden of St Monique, Quebec, is suggested by material that was sent to us for determination by Doctor Foerste.

**Genus Climacograptus** Hall

**Climacograptus typicalis** Hall

This species which was figured but not described by Hall (1865, p. 57) is the most abundant graptolite of the Utica shale, but it appears already in the Trenton and passes into the Eden. It has been fully described and figured, and its distribution noted in the Graptolites of New York (Ruedemann, 1908, p. 407).

Investigations of the shales of the lower Mohawk and upper Hudson valleys carried out since the publication of this memoir by the writer (Ruedemann, 1912) have shown that *C. typicalis* is absent in the Snake hill beds and likewise in the Canajoharie shale, except the very last stage at Dolgeville (Dolgeville beds), but is very common in parts of the Schenectady beds, probably the later stages. It thus does not seem to have reached New York in Trenton time. In the Utica it is the dominant fossil in the lowest division; but continues through all three divisions distinguished in this paper.

*Climacograptus typicalis* still occurs in the Frankfort shale, s. str., but is absent in the Indian Ladder beds; and in the Deer river and Atwater creek shales of the Black river valley, it is replaced by the mutation *posterus*. Still specimens of the character of the true *typicalis* are sometimes met with in the Whetstone Gulf formation, while, on the other hand, the specimens in the Frankfort shale, as those at the Delta dam near Rome, are also narrower than the typical Utica material, but not to the extent of the mutation *posterus*, and besides are still coarser in texture and dimensions than the latter.
Climacograptus typicalis mut. posterus nov.

Plate 7, figure 14

This mutation of Climacograptus typicalis occurs in immense numbers and characterizes the last black shale zones of the Black river valley, namely, the Deer river shale and Atwater creek shale.

It is distinguished from the type of the species by its smaller size (13 to 15 mm average length), the more uniform and more rapid widening (within 8 mm) to a width of but 2 mm (in most specimens only 1.5 mm); the closer arrangement of the thecae (12 to 15 in 10 mm) and the thinner test of the rhabdosomes, whereby it is difficult in spite of their great number to find clear specimens. The thecae are of the character of those of C. typicalis.

The writer has already noticed this mutation in the material before him when engaged in the monographic study of the graptolites of New York, and has described it in Memoir 11, p. 410, from Lees gulf near Turin, as a form that "failed to attain mature characters while outgrowing the young in size." It is there reproduced in text figure 362 (p. 409).

This mutation occurs as a common fossil in the Deer river and Atwater creek shales and has been found in the sections along Moose creek, Mill creek, Atwater creek, Whetstone gulf, Deer river and Lorraine gulf. It is especially characteristic of the Deer river shales, where it is the dominant fossil. It continues, however, into the Atwater creek shale, and even into the lower Whetstone gulf shale, where it is found in the lowest zone, for instance at stations 6 and 8 of the Lorraine gulf section.

Climacograptus putillus (Hall)

There occur minute, narrow climacograptids in rocks varying in age from the Normanskill shale of Chazy age to the Maquoketa shale, of Richmond age, which, principally through their minuteness appear to be identical. Practically all have been identified, on this continent, with Graptolithus putillus Hall; in Canada, whether from the Utica shale (Ami) or Normanskill shale (Lapworth); in the United States whether from the Normanskill shale (mut. eximius Ruedemann), Canajoharie shale (Ruedemann), Utica shale (numerous authors) or Eden shale of the Ohio basin (several authors).

Also in Europe small climacograpti have been identified with Hall's species and Tullberg has named a zone in Scania after it, that is as old or older than our Normanskill shale.
Figures 47, 48 Climacograptus typicalis mut. posterus nov. Two rhabdosomes x 10. Figure 47 Station 1 Whetstone Gulf. Figure 48 Station 2 Whetstone Gulf. Figure 47 Type.

Figures 49–52 Climacograptus lorrainensis nov. Figures 49, 50, 52. x 5, figure 51. x 10. Figure 52 Type. All from Lorraine village.

Figure 53 Glossograptus quadrimucronatus mut. lorrainensis nov. Portion of rhabdosome near sicural end. x 5. Lorraine Gulf, station 6.
Hall's type of *Graptolithus putillus* came from "the Hudson river shale" of Iowa; its locality is the Maquoketa creek and its horizon the Maquoketa shale, which is now placed in the Richmond group.

With the progressive refinement of the stratigraphic division of our Ordovician shales, it has become more and more obvious, that a variety of species is hidden under Hall's name and confusion created thereby. The fact, that some of these small forms are distinctly characteristic of certain horizons and therefore require recognition, has forced us to study them closer for the purpose of separating them.

Text figures 368–72, Graptolites of New York, pt 2, p. 416, which illustrate specimens of "*Climacograptus putillus*" from different localities, already indicate the differences observable in the profile line of the thecae. Still more obvious is this difference between the type of the species from the Maquoketa shale and the form from the Normanskill shale (see Ruedemann, 1908, p. 420, figs. 378–84). The latter was distinguished by the writer as mut. *eximius*. It is shown by its relatively longer, more overlapping and more closely arranged thecae to be a good species, and may therefore henceforth be known as *Climacograptus eximius*.

On account of the much later (Silurian) age of the Maquoketa type, the name *putillus* is better restricted to this alone.

By a close comparison of the graptolites hitherto here united under *Climacograptus putillus*, we have been able to distinguish the following forms:

1. *Climacograptus eximius* Ruedemann. Normanskill shale at Lansingburg (probably at a very high horizon). This type is characterized by its narrow rhabdosome, close arrangement of thecae (16 to 18 in 10 mm) and distinctly climacograptid-character of thecae.

2. *Climacograptus strictus* nov. Canajoharie shale, zone of Glossograptus quadrimucronatus cornutus. This is a well-marked type of somewhat coarser character (see Memoir 11, text figures 371–73). Its rhabdosomes are, on the average, 11 mm long and 1 mm wide. Twelve thecae are counted in 10 mm. The test is apparently stronger than in the later forms, and also the virgula is stronger. The thecal apertures are separated by wide notches, occupying about one-fourth the width of the rhabdosome and one-third or more of the ventral margin. The distal positions of the thecae are parallel to the axis of the rhabdosome and the thecae of the Climacograptid type.
This form is possibly identical or vicarious of C. brevis Elles and Wood (1906, p. 192), which belongs in the Dicranograptus shales, but in some individuals survives into the lower Hartfell shales, or rocks of the age of the Canajoharie shale.

3 Climacograptus tenuis nov. Upper Utica shale, Big brook near Westernville, N. Y.

This form was found in a few specimens near the contact of the Trenton limestone and Utica shale along Big brook, near Westernville, Oneida county, associated with Lasiograptus eucharis. It is characterized by its relatively long (12 mm) and thin (1 mm) rhabdosome, with closely arranged thecae (16 in 10 mm), which nevertheless have a rather loose appearance through the deep, wide notches separating them, and occupying nearly half the ventral margin. This species suggests an emasculated Climacograptus typicalis in the form of the thecae, and may not properly belong in the putillus group.

4 Climacograptus pygmaeus nov. upper third of the Utica shale at numerous localities. This is the most important of the minute Climacograpti, for it is the characteristic graptolite of the uppermost division of the Utica shale. It was figured by us in Memoir 11, p. 416, fig. 376, from Fulmer creek (erroneously Flat creek) near Mohawk, N. Y. It fills the rocks in myriads; often to the exclusion of other fossils, at this locality, as well as at many others about Utica (see sections of Steuben creek, Six Mile creek, Maynards creek, Starch Factory creek, Holland Patent) and in the Black river valley. Nevertheless, it is, on account of its relatively thin test, not readily noticed. Its principal characters are its minute size (6–8 mm), small width (.7–8 mm), maximum width observed 1 mm) and small thecae (14–16 in 10 mm). The thecae are of true Climacograptus character and separated, in the compressed condition, by rather narrow notches.

The specimens occurring in the Frankfort shale belong also to this form.

5 Climacograptus lorrainensis nov. (see plate 7 figures 11–13). Middle Lorraine shale. (Lorraine gulf stations 15–19; and Lorraine village). This form, which rather abruptly appears in the middle Lorraine is 7–9 mm long in the average (one specimen reaches 13.5 mm), 1 mm wide and has 12 to 14 thecae in 10 mm. The thecae are those of a true Climacograptus and the rhabdosomes again are very gradually widening, suggesting a dwarfed gerontic C. typicalis (see text — figs. 49–52).
6 Climacograptus putillus (Hall). Maquoketa shale. The thecae of this species are as much suggestive of Diplograptus as of Climacograptus (Ruedemann, 1908, p. 416 where it is described, and text figures 368, 369 loc. cit.)

In the European graptolite shales, similar minute forms occur, which, undoubtedly, are closely allied to our species. One of these, Diplograptus (Glyptograptus) teretiusculus var. siccatus Elles and Wood (p. 253), occurs in the Glenkiln shales and is a vicarious form of our eximius; another form, here termed Climacograptus strictus is, from the description, indistinguishable from C. brevis Elles and Wood, which, however, appears earlier (in the Glenkiln). In view of the minuteness of the specimens, actual comparison of the types can only settle the question of their relationship.

Family Glossograptidae

Genus Glossograptus Emmons

Glossograptus quadrimucronatus (Hall)

Glossograptus quadrimucronatus was originally described from the black “Utica” shale of Lake St John in Quebec. It is there, according to Raymond (Dresser, 1916, p. 39) associated with Leptobolus insignis, Endoceras proteiforme and Triarthrus glaber. This black shale, now termed the Gloucester formation by Raymond (1916, p. 255) overlies the Collingwood of Ontario and is probably younger than the Utica of New York, which at least in part is of upper Cobourg age. The typical form of G. quadrimucronatus had hitherto not been found in this State, but only a number of mutations which were described by the writer as var. cornutus, approximatus, timidus and postremus (see postea). All of these occur in earlier horizons than the typical quadrimucronatus, namely in the Canajoharie and Utica beds. The typical form is now, however, known from the Atwater creek shale, a Frankfort facies which in the Black river valley follows upon the Deer River black shale, which we believe to be equivalent to the Collingwood shale. It is then probable that the Atwater creek shale corresponds to the Gloucester formation of Canada.

Where the typical G. quadrimucronatus is best developed, as in the Atwater creek shale of the Turin section (Mill creek), it fully reaches the dimensions of the specimens of Lake St John and of Great Britain. The rhabdosomes are there 50 mm long,
3 mm wide and have but 8 to 10 thecae in the space of 10 mm. Also the apertural spines are notably longer than in the earlier mutations and those near the sicular end show in some specimens a tendency to further lengthening, similarly as in the British variety spinigerus. On the other hand there also occur in the Atwater creek beds at Allendale, at the mouth of the Lorraine gulf, specimens that are but 2 mm wide and have 10 to 11 thecae in the space of 10 mm.

The following earlier mutations have been described from this State:

Glossograptus quadrimucronatus approximatus.
Glossograptus quadrimucronatus cornutus.
Glossograptus quadrimucronatus postremus.

The mutation approximatus (Ruedemann, 1908, p. 392) is the expression which the type has found in the Utica and Dolgeville shales of New York. It is smaller in its dimensions, has the thecae somewhat more closely arranged and the apertural spines are little prominent. This is the common diplograptid of the Utica shale and has, on account of its inconspicuous characters been identified with Diplograptus pristis and foliaceus in earlier publications.

The mutation cornutus (Ruedemann, 1908, p. 393) is characteristic of the Canajoharie shale (Ruedemann, 1912) and occurs at the Rural Cemetery near Albany; about Canajoharie; and at Gansevoort, Alplaus, etc. in Saratoga county. Its most important feature is the presence of long spines on the sicular extremity. It is very closely related to Diplograptus (Orthograptus) pageanus Lapworth, which has like spines and is a form distinguished from G. quadrimucronatus, according to the British monographers, mainly “in being shorter and broader, and having more closely set thecae, which are also somewhat different in form and ornament.” In all of these characters, as well as the somewhat fusiform outline of the rhabdosome (Ruedemann, 1908, text fig. 338), our mutation cornutus is a close ally of D. pageanus. It still differs in having the thecae not as closely set (10 to 12 as against 12 to 16 in the latter species). Since D. pageanus occurs in the zone of Dicranograptus clingani of the Hartfell shale, it also corresponds in age to cornutus, and is to be considered a vicarious form.

There occurs, however, in the Canajoharie shale at Waterford
and Mechanicville also a narrow mutation, only about 2 mm wide, with the thecae crowded to 12–16 mm within 10 mm, just as in the British pageanus. This form lacks, however, the long spines at the sicural end and the subfusiform outline. We have termed it (Ruedemann, 1911, p. 394) mutation postremus, under the erroneous impression that these beds were of Frankfort and Lor­raine age.

A still narrower form occurs in the Snake hill beds; it is the mut. pertenuis (nomen nudum) of Bulletin 162.

In the Graptolites of New York, pt 2, p. 483f., several forms have been described under the heading of Lasiograptus bimucronatus timidus. One of these, from the Maquoketa shale at Granger, Minn., is probably a Lasiograptus, as indicated by the patches of integument on the spines (op. cit. text figure 465), although it is difficult to understand that Lasiograptus bimucronatus should reappear in a gerontic form in the Richmond after the long interval from the Normanskill shale.

The finding of a zone in the Utica shale in which the other form, referred to Lasiograptus bimucronatus timidus, is diagnostic, has led to a restudy of this mutation. It is most common along Fulmer creek (erroneously termed Flat creek in Memoir 11) near Mohawk, N. Y. and along Starch Factory creek in Utica, in both sections marking the upper third of the Utica shale. This latter form is a mutation of Glossograptus quadrimumucronatus that properly retains the name timidus. It is easily recognized by its short length (9–10 mm), relatively great width (2 mm), rather abrupt widening of the rhabdosome (not well shown in text figure 464, op. cit.), and the great length of the stout, horizontal apertural spines, which is twice (2 mm) that observed in the mutation approximatus.

Glossograptus quadrimumucronatus inequispinosus nov.

Plate 7, figures 7–10

The Utica shale at Holland Patent and South Trenton, directly above the Trenton limestone but belonging near the base of the third zone, has afforded a peculiar mutation that is characterized by spines of double length (2+ mm) that are found opposite the sixth or seventh pair of thecae, sometimes also opposite the fifth to seventh pairs. In this peculiar character the form exactly corresponds to the var. spinigerus Lapworth of Glossogr.
quadrimucronatus, which singularly enough occurs at the corresponding horizon with Pleurograptus linearis in the Hartfell shales of Scotland. In the vicarious form of Scotland, however, the longer spines appear about the tenth pair of thecae. A third form, which developed a like group of longer spines, is Orthograptus pageanus abnormispinosus Elles & Wood, also from the Scottish Hartfell shales.

A further variety falling into this group has been observed in the Utica shale of Herkimer county (United States Nat. Mus. 54, 354). In this the rhabdosome is very large, reaching a length of 50 mm and a width of 3.5 mm. The abnormally developed spines are over 3 mm long, and situated 8 mm from the sicular end, corresponding to the seventh to ninth pair of thecae in the specimens observed. This form may be considered identical or nearly so with the British mutation spinigerus Elles and Wood. T. S. Hall (1906, p. 277) has described a variety of Glossograptus quadrimucronatus with four prominent spines about 2.5 mm long about the seventh or eighth thecae, from Victoria, Australia. There are thus distinguishable at least three varieties of Glossograptus quadrimucronatus, each with abnormally developed spines, and living at approximately the same time in Scotland, America and Australia, but all three with the prominent spines at slightly different distances from the sicular end. It would thus appear that the same character was developed independently at several places under the stress of searching for better protection or stabilization of the stipes.¹

In the other characters G. quadrimucronatus inequispinosus approaches the typical G. quadrimucronatus, which appears shortly after in the Atwater creek shale, more closely than it does the preceding mutations of the Utica and Canajoharie shale. Its rhabdosomes reach a length of 40 mm, are 2.5 mm wide, the thecae number 14 to 10 in the mature region and the apertural spines are longer and more distinct than in approximatus.

Finally we have before us also specimens of G. quadrimucronatus from the Whetstone gulf formation (Whetstone gulf station 3, Lorraine gulf stations 6 and 7). These differ from the typical form in widening very gradually and having the thecae overlap but one-third their length, whereby the rhabdosome assumes a rather loose appearance. These rhabdosomes attain a length of 35

¹ A fuller statement regarding this homoeomorphic development of so-called species in separate regions has meanwhile been published by the writer (1919, p. 63).
mm, a width of 3 mm and the thecae number 9 and 10 in the space of 10 mm. The apertural spines of the thecae are weakly developed. This mutation may be known as *lorrainensis* (plate 7, figure 6).

Genus *Lasiograptus* Lapworth

*Lasiograptus* (Thysanograptus) *eucharis* (Hall)

*Lasiograptus* (Thysanograptus) *eucharis* was first described and figured by Hall (1865, p. 146) as *Retiograptus eucharis* from the Collingwood shale ("Utica shale") of Lake St John, Quebec. It has been more fully described and figured as *Glossograptus*? *eucharis* by Ruedemann (1908, p. 397) in the Graptolites of New York and finally placed under *Lasiograptus* (subgenus Thysanograptus) by the same author (1912, p. 84).

The species is now known to have its principal development below the Utica shale, namely, in the Snake Hill, Canajoharie and Schenectady beds in New York and the Collingwood shale in Canada. It also enters the Utica, but does not seem to be any more a constant member of the fauna, although still present in the third division about Holland Patent and at Barneveld, Oneida county in the Steuben creek section. But the statement by Ruedemann (1912, p. 85) that it persists into Frankfort age is an error.

I have, however, seen it as an abundant fossil on slabs of basal Eden shale from a locality 1 mile east of Field Station, Ontario, sent to me by E. J. Whittacker of Toronto. It is probably this form and occurrence on which Nicholson based his *Diplograptus hudsonicus*.

Phylum Echinodermata

Class Crinoidea

Family Heterocrinidae

Genus *Ectenocrinus* Miller

*Ectenocrinus simplex* (Hall)

*Heterocrinus simplex* was described and figured by Hall (1847, p. 28) from "the soft shaly portions of the Blue limestone of Ohio, at Cincinnati, equivalent in position to the Hudson river group of New York." It has been more fully described in 1873 (p. 7) by Meek and been made by Miller (1889, p. 242) the
genotype of his genus Ectenocrinus. Bassler (1915, p. 471) records it as occurring in the Eden and lower Maysville of Cincinnati and vicinity. Doctor Ulrich has recognized the species in the impression of a poorly preserved body and arms, collected by the writer at station 9 of the Wood creek section and in beds of lower Eden age.

The stem joints are round and probably have at some stations where the species may occur, not been separated from those of other crinoids.

Genus Heterocrinus Hall

Heterocrinus heterodactylus Hall

Heterocrinus heterodactylus, the genotype, has been carefully described and figured by Hall in volume 1 of the Palaeontology of New York, 1847, p. 279. A still more elaborate description was later furnished by Meek (1873, p. 12). Doctor Ulrich informs us that he has in manuscript an emendation of the species, in which it will be restricted to that form in which the pentagonal (proximal) part of the stem is much longer than in the new species H. difficilis Ulrich, which is commonly associated with heterodactylus. We will therefore not introduce here a description of the crown, but merely point to the peculiarities of the stem joints since it is the latter which crowd the Lorraine shale, while the crowns are extremely rare.

The stem which, as in the whole genus, is long and stout in contrast to the small body or crown, consists near the latter of distinctly pentagonal segments, which have been well figured by Hall. These segments with their quinquepartite articulating sur-
faces, consisting of five radiating petal-like gliding faces and radially striated interspaces for the connective tissue, are a very characteristic fossil of the Whetstone gulf shale. According to Meek, the stem, near the body, is composed “of alternatingly thicker and thinner pieces; the latter not forming continuous disks, but consisting each of five minute sections, disconnected from each other, and ranged as minute transverse nodes coincident with the five angles of the column. Farther down the column gradually becomes nearly cylindrical, and the little intercalated pieces more and more developed, until they coalesce and form complete discs, scarcely distinguishable from the others.”

Hall recorded the species as occurring throughout the shaly part of the “Hudson river” (Lorraine) group in New York and in the “shaly strata near Cincinnati, Ohio.” In the latter locality it is, according to Bassler, an Eden form, and in New York it is likewise found throughout the Whetstone gulf formation. The two crowns here figured (text figures 54 and 55) are from the neighborhood of Rome.

**Heterocrinus difficilis** Ulrich Ms.

This species, formerly comprised under *H. heterodactylus* Hall, will be described by Doctor Ulrich in a forthcoming paper. It is, according to information kindly furnished by him, distinguished from the genotype in having a much shorter pentagonal portion of the stem near the body.

The specimen was found by the writer at station 1 of the Wood creek section (zone I of Whetstone Gulf formation).

**Genus Iocrinus** Hall

**Iocrinus cf. subcrassus** (Meek & Worthen)

The United States National Museum contains, in its collection from the lower Lorraine shale (Whetstone Gulf formation), 1½ miles east of Rome, N. Y. (Rust collection 354, no. 23, 539), a calyx and stem of a small Iocrinus that, although not sufficiently preserved for positive determination, does not exhibit any characters excluding it from the well-known genotype of Iocrinus, namely, *Iocrinus subcrassus* (Meek & Worthen). Since this species ranges from the Trenton to the Richmond in the Ohio basin, it is of little value for the purpose of correlation.

*Iocrinus subcrassus* has been fully described and well figured as *Heterocrinus? (Iocrinus) polyxo*

The characteristic stems, composed of strongly pentangular, alternating thick and thin columnals, are seen frequently in the shale of the lower Lorraine and indicate that the species was much more abundant than the rarely preserved calyces would suggest.

Family Melocrinidae

Genus Glyptocrinus

Glyptocrinus decadactylus (Hall)

Glyptocrinus decadactylus was described by Hall (1847, p. 281) from western material, but also recorded as occurring "in numerous localities in New York," where, it is stated, fragments of the columns are abundant, but the body was never found. The supposed occurrence in New York of this common and characteristic species of the Fairmount division of the Maysville at Cincinnati, and in Indiana and Kentucky (Bassler) is therefore based entirely on the similarity of columnals occurring in our Lorraine with those of the western form. Since, however, the columnals are variable in form according to their relative position to the body from subpentagonal to round and similar to those of other associated crinoids, it is impossible to recognize the species from its columnals.

Pentacrinites hamptoni Emmons

Emmons, in the Second District Report (1842, p. 402) and Vanuxem in the Third District Report (1842, p. 65) figured as Pentacrinites hamptoni one of the characteristic pentagonal, quinque-partite stem joints from the Lorraine shales among the index fossils of the latter.

The name has no standing, since no species much less a generic term could be based on a columnal, however common, and especially in this case, where several species have similar columnals. The name has, however, appeared still in late years in fossil lists of the Lorraine beds in the descriptions of New York quadrangles (for example, Port Leyden by W. J. Miller).
Phylum Vermes
Class Chaetopoda
Order Tubicola
Genus Spirorbis Daudin

Spirorbis philorthoceras nov.

Text figures 56 and 57

Description. Tubes involute in one plane, forming about two volutions, which together attain a diameter of 4 mm; attached to cephalopod shells and flat on the under side and rounded on upper side; aperture circular and in mature specimens turned upward. Surface furnished with sharp, forwardly concave costae or annulations.

Horizon and locality. Upper Utica shale at Holland Patent.

Remarks. The minute spirally enrolled tubes here described as Spirorbis philorthoceras cover the surface of some large specimens of Geisonoceras tenuitextum in great profusion. Their size is quite uniformly 3–4 mm. In many cases only the inner mold is left, which is smooth and in the flattened condition resembles a small Liospira; in others, where the exterior is preserved the rounded outline and the sharp crests are well shown. The latter give often the impression of a septate condition, recalling the fact that Hall's Microceras (1845, p. 249) was based on minute, free shells that suggested a chambered shell to him. There have been two species at least described from the Maysville of the Ohio basin, namely, S. cincinnatiensis Miller and Dyer and S. lovelandensis James. Hall (1888, Suppl. p. 17) on reinvestigating the former species found it to be an early coiled stage of development of a Cornulites with which it is associated. This possibility appears to be excluded in our case by the uniformity and compactness of the coils of the tubes and the absence of any associated specimens of Cornulites, not a single straightened tube having been observed among hundreds of coiled specimens.

In Cornulites immaturus Hall (op. cit. p. 18) we have, however, a minute Cornulites which also has a serpuloid growth stage and that also occurs at Holland Patent. In that form only a small number of specimens are imperfectly coiled and most individuals straighten out from the beginning. It could
then be assumed that under certain conditions most or all individuals of this Cornulites grew straight and under other conditions all assume an enrolled position of the tube. If this should be proved to

Figures 56, 57 *Spirorbis philorthoceras* nov. Figure 56 Conch of Geisonoceras with attached tubes of Spirorbis in natural size. Figure 57 Specimen X5.

Figure 58 *Serpulites lorrainensis* nov. Natural size.

Figures 59–62 *Serpulites intermedius* nov. Figures 59–61 Natural size. Figure 62 Apparent distal extremity of original of figure 61, X3.
be the case, the species here described would become a synonym of *Cornulites immaturus*. With our present knowledge, however, it seems a safer policy to keep the two forms distinguished, since one is habitually closely coiled and the other only loosely coiled at times.

At any rate, forms of Spirorbis are well known and abundant in the Ordovician rocks of Europe and there is therefore no reason to assume their absence in our rocks of the same age.

**Genus Serpulites** Murchison

**Serpulites angustifolius** (Hall)

The interesting fossil described by Hall (1847, p. 261) as *Sphenothallus angustifolius* from the "Utica slate between Canajoharie and Schoharie," is a fairly common and characteristic form of the upper Canajoharie shale in the Mohawk valley and about Dolgeville (Dolgeville shale), but also reaches the upper Utica at Holland Patent.

The species is characterized by the rapid expansion of the cones. Its ontogeny as well as structure have been described in detail by the writer (1897, p. 701), and its relationship to *Conularia* fully discussed in a later publication (1916, p. 83).

**Serpulites crassimarginalis** (Ruedemann)

*Original description* (Ruedemann 1916, p. 87). Large, transversely elliptic cone of very gradual expansion attaining a length of 95 mm and width of 6 mm. The marginal welts are very thick (1.3 mm wide); the basal disk apparently small. The smaller rate of expansion and the thick marginal welts are the principal characters distinguishing this species from *Serpulites angustifolius*.

This species occurs in the Utica shale\(^1\) at Holland Patent, N. Y., and other localities.

It has also since been found by us in the black shale (Deer river shale) at the base of the Lorraine gulf section, and in the Frankfort shale at Spoon creek near Utica and the Delta dam near Rome.

**Serpulites gracilis** Ruedemann

This species has been described (Ruedemann, 1916, p. 87) from the upper Canajoharie shale at Dolgeville and the Utica shale at Holland Patent.

We have since observed it also in the Frankfort shale at Frankfort, N. Y.

\(^1\) Should read "black basal Frankfort shale."
Serpulites dissolutus Billings

Billings (1865, p. 56) has described as *S. dissolutus* a worm tube from the Trenton of Montreal and Ontario, to which later forms of different ages from Manitoba have been referred by Whiteaves (1897, p. 160, 240). As a result of this wide conception which has been given the species, its range is stated by Bassler (1915, p. 1157) as extending from the Black River to the Richmond. While Billings did not figure his species, he gives very careful measurements of three typical fairly perfect specimens. If one plots these on paper, one gets a form that is fairly rapidly expanding (at an angle of $5^\circ$ in two, $4^\circ$ in one specimen) and attaining considerable width (7.5 mm). The various forms which we have described (1916, p. 86 ff.) from the Ordovician of New York and which would be comprised under *S. dissolutus*, differ widely in their relative rates of expansion and the size attained and are constant in these characters in their respective, rather restricted ranges. It seems preferable, therefore, to restrict *S. dissolutus* to the Trenton form on which its original description was based. The form described by Whiteaves from Manitoba is more slender, for although imperfect at the basal end, it reaches in a length of $1\frac{3}{4}$ inches but a width of $1\frac{1}{2}$ mm (Whiteaves, ibid.).

Serpulites lorrainensis nov.

**Text figure 58**

**Description.** Tube very slender, subcylindric, attaining a width of but 2 mm in a length of 65 mm (imperfect at basal end, which is 1 mm wide). Marginal welts relatively thin, but connecting test relatively stronger than in other species. Surface finely granulate.

**Horizon and locality.** Lower Lorraine (Whetstone Gulf) shale at Tolman Gulf, Jefferson county, N. Y. and other localities.

**Remarks.** This species is in outline and probably also in character of surface nearest related to the Canajoharie and Utica species *S. gracilis*, differs from it, however, in the stronger test and more strongly developed lateral welts. The finely granulated test between the smooth lateral welts distinguishes it from the other species of the Cincinnatian rocks, save *S. gracilis* which may have had a similar test.

Serpulites intermedius nov.

**Text figures 59-62**

**Description.** Tube slender, circular in section in the proximal part, becoming broadly elliptic in adolescent and mature stages, with strong lateral welts; increasing at such a rate that the angle is about
3°. Basal disc small. Surface smooth or furnished with fine transverse lines or wrinkles.

Horizon and locality. Frankfort shale at Holland Patent, N. Y.

Remarks. This species, in its rate of growth is intermediate between the distinctly more slender Canajoharie and Utica species, *S. gracilis* and the larger and more rapidly widening *S. crassimarginalis*, an associate member of the Frankfort shale fauna. While in *S. intermedius* the angle is constantly, in a considerable number of specimens, about 3°, it amounts in *S. crassimarginalis* to 5–7°. The marginal welt is distinctly thicker in *crassimarginalis* and the round proximal portion much shorter. While the largest specimen of *S. intermedius* measures 70 mm and is but 3–7 mm wide at its distal extremity, *S. crassimarginalis* attains a length of 100 mm and more, and a width of 8.5 mm and is thus a larger form with a greater rate of growth and thicker tubes.

Genus *Protoscolex* Ulrich

*Protoscolex cf. covingtonensis* Ulrich

Text figures 63 and 64

The argillaceous black shale at Holland Patent transitional from the Utica to the Frankfort beds, has afforded two small specimens of worms, clearly belonging to Protoscolex Ulrich, but doubtful as to their specific relations.

Figures 63, 64 *Protoscolex cf. covingtonensis* Ulrich. Two specimens x8. Figure 63 drawn before preparation.

One of these is 10 mm long, 1–2 mm wide, of uniform width, and so closely segmented that seven segments are counted in one mm. The
extremities are not distinct enough to enable one to distinguish the anterior and posterior ends.

In width of body and the character of the very narrow and smooth segments, of equal width, this specimen well agrees with Protoscolex covingtonensis Ulrich (1878, p. 89), from the Economy member of the Eden at Covington, Ky. The horizon of the New York specimen is so high in the Utica that the fossil may well be considered as identical with, or but little differing in age from, the Kentucky species. The fact that the Covington specimens are 3 to 4 times longer, which is the single difference observable, is of little importance in this group of organisms, and especially so since our specimens may be incomplete at one or both ends.

The other specimen is a little coarser in structure and its segments are wider (4 in 1 mm), not quite one-third the width of the body. It is thus comparable to P. simplex Ulrich, another Economy form.

Protoscolex giganteus nov.

Plate 9, figure 8

Description. Body large, long cylindrical (?), of nearly uniform width throughout, save a slight contraction posteriorly of the head (?) and a rapid contraction toward the posterior extremity. Very closely and distinctly segmented. With wide alimentary canal and a marginal fringe, which widens posteriorly. No distinct setæ or appendages observed.

Measurements. Length 152 mm (incomplete), average width of segmented portion 10 mm; of fringe 2 mm. Length of segments 1 mm; width of alimentary canal about 3 mm.

Horizon and locality. Frankfort shale near Rome, N. Y.

Remarks. This fossil might, at first glance, suggest an extremely closely jointed crinoid stem with wide central canal. It lacks, however, the calcareous substance shown by crinoid columns in the Frankfort shale, and consists only of a broad carbonaceous, partly iron-stained band, with a median raised axis, apparently through the filling of the central (alimentary?) canal with mud. The segments appear as distinct annulations, depressed in the middle and slightly raised along the joints. Where the thin annuli are worn away, the mud-filled canal appears as a solid smooth cylindric body.

What appears as the head of the organism, may be only a flattened out transverse section. It shows little more than a circular outline with a large circular, central opening. The other extremity of the rigidly straight body is slightly bent and abruptly contracting. The
fringe shows, besides some impressed lines parallel to the axis of the fossil, a faint system of lines that are directed obliquely backward and that suggest the presence of lateral rows of setae. Owing to the mode of preservation of the specimen, it is doubtful whether it was originally round cylindrical or broadly elliptic in section.

We have referred this species to the genus Protoscolex Ulrich (1878, p. 89) because the latter was erected for similar forms of uniform width and close segmentation; although the species constituting that genus are much smaller in size and seem to lack the fringe of supposed setæ. *Hammatopsis scanicus* Hadding (1913, p. 29) approaches our form in dimensions and segmentation. It is surrounded by a glossy border, which, according to Hadding, probably resulted from the decomposition of the organism. It lacks the distinct elevated axis of our form and apparently, with our present knowledge, should also be referred to Protoscolex.

**Genus Cornulites** Schlotheim

**Cornulites immaturus** Hall

The Utica shale of Holland Patent has afforded a unique group of specimens of a primitive Cornulites attached to an Orthoceras and figured by Hall as *C. immaturus* (1888, p. 18, pl. 115, fig. 40). It is stated that this "species is known only in an early serpuloid stage of growth, and may eventually prove identical with the forms occurring in the Cincinnati group."

We have not seen any other specimens of this peculiar type.

**Cornulites progressus** nov.

Plate 10, figures 8-11

The organic remains of the Lorraine group here discussed under the heading of *Cornulites progressus* were first mentioned by Emmons (1843, p. 404) as Tentaculites sp. and stated to be very common in the Lorraine, especially its upper part. Hall, later (1847, p. 284) referred them to his Trenton species *Tentaculites ? flexuosa*, stating:

This species is equally as abundant in the rocks of the Hudson river group as in the Trenton limestone. In the latter it often attains a greater length, and is nearly straight or simple curved. The flexuous character, therefore, may not be constant or essential in distinguishing the species, though I have not seen perfectly straight specimens.

This identification of the Lorraine forms with the Trenton
species has endured to the present day and the species is recorded as ranging from the Trenton to the Maysville in the Ohio basin and from the Trenton to the Lorraine in New York. (See Bassler, 1915, p. 279.)

In (1888, p. 8 ff.) Hall has exhaustively discussed the relations of Cornulites and Tentaculites and referred the Ordovician forms to Cornulites on the ground that they are more or less curved, longitudinally striated in a manner not observed among true Tentaculites and attached, at least with their bases, to some foreign body. It is further suggested that the various Cincinnati species are but phases of a single form; an exception, however, being made for Cornulites flexuosus as represented in the Trenton, which is considered as probably a distinct species, because somewhat more slender and more flexuous than specimens of the same degree of development from the region around Cincinnati. At the same time, it is stated that the specimens from the Lorraine are still more slender and frequently regularly curved, not flexuous as in the typical flexuosus from the Trenton limestone.

More recently the characters of the Lorraine form have been fully described by Foerste (1914, p. 314 f) as follows under Cornulites sp.:

At the Strophomena nasuta and Trinucleus horizons, between the railroad bridge, about a mile east of Pulaski, and a point several hundred yards westward, down the stream, there is a form of Cornulites with a free habit of growth, and practically straight or only slightly curved. These straight forms are known usually as Tentaculites. At the initial tip it probably was attached to some other organism, but no evidence of such attachment was found. The tubes are crossed by annulations, which are rather angular on the crest, sloping with about equal rapidity into the concave constrictions both above and below each annulation. Tube very thin, the interior cast also annulated; annulations sloping gradually in the distal direction, and abruptly on the proximal side; in fact, on the proximal side these annulations often are slightly incurved. Exterior with very fine and numerous longitudinal striations, often alternating slightly in size. At each annulation these longitudinal striae begin as very fine striae on the distal side of the crest, dip into the constricted parts, and become stronger on rising up the proximal slope of the next annulation. Of these longitudinal striae there are about 8 or 9 in a width of 1 mm around the circumference, with an equal number of still finer, intermediate ones, visible under a lens in specimens preserved in fine grained strata. Transverse striations are present in some specimens, but can be seen only with a magnifier and under strong cross illumination. The length of the
specimens at hand scarcely exceeds 15 mm. This is the species figured by Hall on plate 78 of the Paleontology of New York, in volume 1.

Two miles west of Worthville, on the road to Lorraine, another form occurs associated with Trinucleus and other fossils suggesting a fauna very similar to that east of Pulaski. In this form of Cor- nulites the annulations also are rather sharp along the crest, but they tend to slope more rapidly on the distal than on the proximal side. Their chief characteristic, however, is the coarseness of the longitudinal striae, which becomes so strong on ascending the proximal slopes that they give an almost nodular or scalloped appearance to the crest of the annulations. Of these nodules there are about 5 in a width of 1 mm around the circumference. Under strong cross illumination very fine intermediate longitudinal striae can be seen, a single node sometimes representing the distal termination of two or even three striae. Transverse striae are readily distinguished under a lens in some specimens.

Although the two forms here described present quite a different general appearance, the second may be only a more vigorous form of the first, and a much more extended study is necessary to determine their degree of relationship.

In referring these tubes to Cornulites, the writer has merely followed Hall. Cornulites flexuosa, Hall, was founded on a form from the Trenton limestone, at Lowville, New York. I have been unable to identify either form, with certainty, with described species from Cincinnatian rocks, and the descriptions here given are intended merely to call attention to the chief characteristics observed, with the view of further collecting.

While recognizing the differences between the two forms observed by Foerste, we could not convince ourselves that they are more than varietal expressions of one type because there occur intermediate forms at Worthville and both extreme varieties are still distinguished from other species by certain common characters that to us appear more important than the differences cited. These common characters, in our opinion, suggest a transitional stage from Cornulites to Tentaculites. They are:

1. The markedly straight form of the tube in contrast to the flexuous and bent tubes of the Ordovician species of Cornulites, only the tip in this species as a rule being slightly curved, as if suggesting an ontogenetic stage recalling a bent ancestor.

2. While Cornulites is typically attached with its full length, as is also the Cornulites flexuosus of the Trenton, and Tentaculites is free, we have not found Cornulites progressus attached and if it was so it could have been only attached temporarily with the tip.
While Cornulites is characterized by longitudinal sculpture lines and Tentaculites by transverse ones, the present species exhibits both in both the Pulaski and Lorraine shale varieties; the longitudinal striation still predominating, but the transverse being also distinctly visible.

The thinness of the wall and the character of the interior annulations which slope gradually forward and inward, are features more suggestive of Tentaculites than of Cornulites.

Cornulites progressus is thus a form that has progressed on the way from the Ordovician Cornulites to the Silurian Tentaculites in the nearly straight form, and the thin wall, which characters are concomitant with the tendency to detachment—but which is still referable to Cornulites on account of the dominant longitudinal striae and the probable attachment, at the base or in an early stage. It should be mentioned in this connection that Tentaculites is here understood in the restricted compass given it in Europe, where one sharply distinguishes between the transversely striated, acutely pointed Tentaculites, possibly a worm tube, and the much thinner, longitudinally striated Nowakia which possesses an embryonal bulb at the proximal end; and which quite probably is a pteropod. On this side of the Atlantic this latter group, which is typically represented by the Marcellus and Genesee species Tentaculites gracilistriatus, is still retained within Tentaculites (Zittel-Eastman, 1913, p. 571).

Genus Arthraria Billings

Arthraria magna nov.

Text figures 65 and 66

The Pulaski section below the railroad bridge contains a gray sandstone bed covered with large dumb-bell shaped fossils of very striking appearance. The bed was formerly broken for flagstone and some of the flagstones, which have not been replaced as yet by cement walks, may still be seen in the northern outskirts of the village of Pulaski. They exhibit hundreds of these dumb-bell like bodies.

The dumb-bells consist of two circular bodies, 30 mm and more in diameter and about 55 mm apart, measured from margin to margin, connected by a straight channel on the surface, about 5 mm wide. The circular bodies are funnel-shaped depressions in the

1 The interior structure of the wall which is quite different in the two groups, could not be studied in our specimens.
sandstone filled with the dark-gray mud, that forms a thin film on the sandstone bed. This dark mud shale is distinctly arranged in concentric welts and depressed in the middle, as if sunken in when the sediment hardened. Also the connecting channel is filled with this mud. Where these bodies are broken through and a section is exhibited, it is seen that the circular bodies contract downward into more or less slanting tubes, identical with the worm burrows that perforate the rocks in all directions, but mainly in vertical direction.1

A similar fossil was found in the Whetstone gulf shale at station 9 of the Whetstone gulf section. Here the two circular bodies are unlike, the larger is 30 mm in diameter, the smaller about 14 mm, the connecting tube is 55 mm long, but only 2 mm wide, suggesting a different species of worms. The specimen represents only the mud-filling of the dumb-bell like depression, adhering to the underside of the succeeding sandstone stratum but it shows distinctly

1 From recent work of Schindewolf (Ueber Spuren mariner Würmer im Mittleren Buntsandstein Oberhessens; Centralbl. f. Min. etc. Jahrb. 1923, No. 21, p. 662-70) and of Soergel (Beiträge zur Geologie von Thüringen, N. Jahrb. vol. 49, Beilageb. 1924, p. 510-49) it becomes probable that the connecting channel resulted from the settling of the mud between the two apertures of a U-shaped worm tube, the settling taking place along the "Spreite" or the vertical plane along which the worm from time to time deepened his burrow.
the beginnings of the worm tubes in the centers of the shale disks and a faint concentric structure.

In outline, these bodies suggest Arthraria Billings and especially A. biclavata Miller, an Eden fossil of Cincinnati and vicinity (Miller, 1875, p. 355). The latter is, however, according to Miller but an impression and Foerste has lately described Arthraria (Foerste, 1917, p. 292) as consisting of "peculiar gouged-out markings" on intraformational pebbles. Billings's genotype. A. antiquaria, however, may well consist, judging from his description, of fossils having the same origin as those here described.

Genus Arthrariella nov.

Arthrariella lorrainensis nov.

Plate 10, figure 7

A bed of argillaceous shale at station 9 of the Whetstone gulf section is filled with a problematic fossil that has not been observed in any other section but seems identical with a form described and figured by Hall (1847, p. 264, pl. 70, fig. 2) as Palaephycus sp. indet. from the "central portion of the group (Lorraine) near Rome, Oneida county, and in Lewis and Oswego counties." Our material also comes from Lewis county and we consider it possible that this fossil which has been found at various outcrops of the central part of the Lorraine may prove of importance in marking a horizon.

Hall describes the fossil as follows:

This species occurs in short, small fragments, often quite covering the shaly laminae in some parts of this group. It appears to have been a succulent plant, but no definite character can be assigned to it in the present state of our knowledge. The specimens figured are in a fragment of slate presenting the usual aspect of the species. It is often found in smaller and in larger fragments, both covering the surfaces and penetrating the thin arenaceous layers.

Our material consists of straight to gently curving cylindric tubes, 1 mm wide and of varying length (5 mm to 30 mm, the latter an exceptional case), most specimens being about 10 mm long. The tubes which at first glance suggest worm burrows, have a real carbonaceous wall although filled with the sandy matrix; they are, in most cases, terminated by straight-edged margins, suggesting an articulation, and frequently widen slightly near their extremities. They were consistent enough to be but slightly compressed, do not penetrate the rock in all directions, but lie upon
the bedding plane and do not penetrate each other, but terminate distinctly against each other in several cases. They could, therefore, not have been worm burrows, but might have been worm tubes, the fragments of which are now scattered over the bedding planes. The tubes are sometimes sharply twisted and in at least two cases they bear at their ends wedge-shaped extensions, which however, may be due to a bursting and flattening of the tube. The tube walls are smooth outside and inside; in some specimens low nodes are visible, nearly as wide as the tube and with a shallow central depression, the whole suggesting attachment scars.

The specimens figured by Hall are wider and relatively shorter and their extremities are rounded. He referred his material to the algae and placed it under his genus Palaeophycus. A variety of things has been referred to that genus, some distinctly worm burrows, others seaweeds. Taking the first species \( P. \text{ tubulare} \), a Beekmantown form, as the genotype, it is obvious that the species here described, has nothing in common with that genus, for \( P. \text{ tubulare} \) represents branching and anastomosing cylindric bodies, either worm burrows or seaweeds. On the other hand, a genus Arthraria has been erected by Billings (1874, p. 66) for short cylindric stems with an expansion at each end. This has been lately referred to by Foerste (1917, p. 292) as consisting only of “peculiar gouged-out markings,” probably the result of water action.

Our species neither possesses the dumb-bell like terminations of Arthraria, although suggesting something of the kind by a slight widening in some specimens, nor the lateral welts of Serpulites (Ruedemann, 1916, p. 84); we therefore propose to distinguish this and similar tubes that suggest an articulated structure as \( \text{Arthrariella} \) from Palaeophycus, Arthraria and Serpulites, leaving the question open whether they are derived from algae or worm-tubes.

Genus \textit{Lonchosaccus} nov.

\textit{Lonchosaccus uticanus} gen. nov. et spec. nov.

Plate 8, figure 1

The upper Utica shale at Holland Patent has afforded a considerable number of large masses of variously shaped carbonaceous bodies, most of which are now in the Rust and Walcott collections in the U. S. National Museum and the New York State Museum. These bodies have been considered as seaweeds and referred to Discophycus. While many of the thick, coriaceus, subcircular patches
undoubtedly are of algal origin, others have been recognized by the writer as sponges and described as such in this paper; others again were seen to be complete exoskeletons of eurypterids, that had drifted into round bundles. The genera Eurypterus, Eusarcus, Dolichopterus, Pterygotus and Hughmilleria have been recognized and the species will be described in the second part to be published later.

There have also turned up some problematica. One of these is described here, as *Lonchosaccus uticanus*.

The fossil has the form of a bent bag, more than twice as long as wide. It had a thick, substantial wall, now carbonized and to which is still attached a small brachiopod. The two extremities are drawn into apertures, one (the upper in the figure) is very distinct and provided with longitudinal folds, suggesting strong contraction of that part; the other is quite indistinct.

The surface of the body is smooth and there are no traces of segmentation, surface sculpture or harder skeletal parts of the integument.

We have placed this fossil with the annelids, being well aware of the lack of evidence for such a taxonomic reference. It has been suggested to us that the specimen might be comparable to *Ottoia prolifica* Walcott, one of the annelids described by Walcott in his sensational series of discoveries of fossils from the Middle Cambrian Burgess shale of British Columbia. While our form undoubtedly bears a considerable similarity in outline to *Ottoia prolifica*, it lacks the proboscis, oral hooks, annular lines and segments of that interesting organism.

The lack of structure of the fossil leaves the field open to various assumptions; thus one might suspect the form of having belonged to the Siphunculoidea, where Anmulata of similar shapeless unsegmented bodies are known in the adult stage; or to the Holothurians which through Walcott's discoveries are also known to extend back to the Middle Cambrian. But our specimen shows no trace of series of tube feet or calcareous spicules of the integument. The thick carbonaceous test suggesting an original cellulose substance of the wall and the general form of the body lacking all surface structures, would even permit one to think of the ascidians which also possess a similarly folded oral aperture. But in the absence of positive evidence instead of the largely negative one now available, speculation on the taxonomic position of this fossil is unproductive of results.
Class Steleroidea
Subclass Asteroidea
Family Promopalaeeasteridae Schuchert
Genus Mesopalaeeaster Schuchert

**Mesopalaeeaster (?) lanceolatus** Schuchert

Schuchert (1915, p. 82) has described and figured as *Mesopalaeeaster (?) lanceolatus* a small star-fish from the black shale near Rome which has furnished the specimens of *Triarthrus eatoni* preserving the entire ventral anatomy. Two specimens (cotypes) collected by the late Professor Charles E. Beecher are in the Museum of Yale University. The black shale containing these remarkable fossils while currently cited as belonging to the Utica shale, is intercalated in gray Frankfort shales.

Phylum Molluscoidea
Class Bryozoa
Subclass Gymnolaemata
Order Cyclostomata
Family Diastoporidae Busk
Genus Stomatopora Bronn

**Stomatopora arachnoidea** (Hall)

Text figures 67 and 68

Hall described and figured this species as *Aulopora arachnoidea* in the Palaeontology of New York, vol. 1, 1847, p. 76, from material obtained in the blue shaly limestone of Ohio and Kentucky, equivalent to the Trenton limestone of New York. It was first recorded from the Cincinnati group by Nicholson (1875, p. 216) and has lately been described by Bassler (1911, p. 60) from the Ordovician of Russia.

The figure given in text figure 67 shows the aspect of the dense growth of *S. arachnoidea* on a carapace of *Isotelus stegops* in the Lorraine shale, where the substance of the zoarium always is largely dissolved.

*S. arachnoidea* is a form of wide range, for it begins in the Trenton limestone and continues into the Richmond, and it is known from a wide area in the United States and Canada, and also occurs — in the Baltic provinces of Russia — in the Echinospherites limestone, Kuckers shale and Lyckholm limestone, that is, has a similarly long range as on this side of the Atlantic.
In the Lorraine group we have observed it at stations 1 and 9 of the Wood creek section (Whetstone gulf formation), station 22 of the Lorraine gulf section (Pulaski) and in black shales of the same formation in the Rust collection from the neighborhood of Rome. Fine examples were also seen in drift material from the limestone of the Upper Pulaski formation, attached to Modiolopsis.

Genus Corynotrypa Bassler

**Corynotrypa inflata** (Hall)

This minute incrusting bryozoan was first described by Hall as *Alecto inflata* (1847, p. 77) from the Trenton limestone of New York. It was later successively placed under Hippothoa
(Nicholson, 1875) and Stomatopora (Vine, 1881) where it rested until Bassler (1911, p. 515) created the genus Corynotrypa for those forms which differ from the typical, well-known Stomatopora in having the proximal end of the zooecium distinctly constricted.

Ulrich (1895, p. 118) has already pointed out that in the Trenton or typical form the zooecia, as a rule, are less swollen and the adnate zoarium divides less frequently than in the better known Cincinnati form; that, however, no distinction can be based on these characters, since they overlap into both the Trenton and Cincinnati beds.

Corynotrypa inflata ranges from the Black River to the Richmond and occurs from Minnesota and Tennessee to New York and Canada. Bassler has also recognized it in the Middle Ordovician (Wesenberg) of Esthonia, Russia. In New York it is known from the Rysedorph hill conglomerate (Ruedemann, 1901, p. 12), the Glen Falls limestone at Canajoharie (Ruedemann, 1912, p. 21), and the Trenton limestone at Trenton Falls, and other localities. It is not known from the Utica shale. In the Lorraine beds we have observed it as a common fossil, upon brachiopod shells and trilobite carapaces, in the Whetstone gulf formation in the Wood creek section at station 1, Mill creek section at station 12, and on material of the Rust collection from the neighborhood of Rome. Being easily overlooked, it is undoubtedly more common than here recorded. In the shale of the Whetstone gulf formation it is only poorly preserved as, impressions, the calcareous zooecia being dissolved.

Corynotrypa delicatula (James)

This form originally described but not figured by James (Palaeontologist, no. 1, 1878, p. 6) as Hippothoa, is also known as Stomatopora proutana Miller and by several other names. Bassler (1911, p. 506) has a full account of the species.

C. delicatula is, according to Bassler, an abundant fossil, beginning with the Stones River, in practically all of the Middle and Upper Ordovician and earliest Silurian (Richmond) formations of North America. In Europe the species is less abundantly represented but is known from several of the Middle Ordovician formations of the Baltic provinces of Russia.

In the Lorraine formation this species has been observed at station 1 (fide Ulrich) and station 3 of Wood creek section, and in an outcrop just above Lorraine village, where it is attached to Trocholites planorbiformis, but is undoubtedly more com-
mon than would appear from these scattered occurrences. Like the preceding species, it is very liable to be overlooked on account of its small size and attachment to shells and unfavorable preservation in the shale.

Genus *Proboscina* Andouin

*Proboscina* sp. cf. *frondosa* (Nicholson)

A peculiar fossil, here reproduced by text figure 68, is unfortunately preserved only as an impression of the basal portion of a bryozoan, that is parasitic, in association with *Corynotrypa delicatula* upon the shell of Sinuites. The arrangement of the zooecia in double and threefold series suggests that the specimen is a branch of a *Proboscina* like *P. frondosa* or *auloporoides*. These latter are both Maysville and Richmond species and it is quite probable that the fragment represents an earlier species. Its locality is the Whetstone Gulf shale of the neighborhood of Rome (Rust collection.)

Family *Ceramoporidae* Ulrich

Genus *Spatiopora* Ulrich

*Spatiopora lineata* Ulrich

Walcott (1883, p. 22) has described as *Sagenella ambigua* a small bryozoan parasitic upon Orthoceras shells from the Utica shale at Holland Patent. This species has not been recognized by the authorities (Nickles and Bassler, 1900, p. 397; Bassler, 1915, p. 1135) on account of its scanty description, and the knowledge or assumption that as in the Cincinnati region, the parasitic growths on Orthoceras comprise various genera and species. The writer’s study of our Utica material has indeed shown the presence of several incrusting forms in the Utica shale.

Nevertheless, Walcott’s description saying that the cells “are arranged in regular, parallel series over most of the surface, quadrangular and oblong shaped in the parallel series,” leaves but little doubt that he had before him one of the forms here referred as mutations to *Spatiopora lineata*, Ulrich. Unfortunately, the specimens are, in the shale, in which all calcareous parts are dissolved, preserved as impressions only and an adequate description of the structure of the zooecia is impossible or only made possible by reference to the better preserved species of the Cincinnati region.

For the original description of *S. lineata* see Ulrich (1883, p. 167).

We have in the Utica shale, two forms which can be brought under *S. lineata*, one, in the upper Utica shale agrees very well
with Ulrich’s description and figure. This shows five or six zooecia within the space of 2 mm measured in the longitudinal direction of the cells, exactly as Ulrich’s and Bassler’s reliable figures indicate for *lineata*. The acanthopores are, however, distinctly more prominent and the points of junction of the cell walls more thickened than in the mentioned types. This we will distinguish as *Spatiopora lineata crassijuncta*.

Another form occurs in the upper Utica shale at Holland Patent. In this (plate 10, figure 6) the cells, though very strikingly arranged in linear rows, are considerably smaller, numbering 8 or 9 within the space of 2 mm in their longitudinal direction, and acanthopores, as well as maculae are hardly noticeable. This form we will term *Spatiopora lineata compacta*.

A third form may be mentioned in this connection, although it occurs only in the black shale at Dolgeville and is probably older than the basal Utica shale or of Canajoharie age. It is essentially like the *S. lineata compacta* but shows long, narrow, parallel monticules of the shape of those of *Spatiopora montifera* Ulrich, only much smaller (about 4 mm). In some cases all traces of the zooecia have disappeared except these monticules and the fossil gives the impression of a Berenicea or Diastoporina but since no cell apertures are observable on the elongate projections that sometimes cover the entire surface sculpture of a Geisonoceras, it is to be assumed that the extremely thin zoarium has entirely disappeared, leaving only the monticules. Where the zooecia are still recognizable they are very accurately aligned numbering about 6 or 7 in the space of 2 mm. This form may be cited here as *S. lineata hirsuta*.

The typical *lineata* occurs in the Maysville (Bellevue) of Hamilton and Cincinnati, Ohio. *S. lineata incepta* is found in the Black River (Decorah) of Minnesota and the Wesenberg limestone of Esthonia. The two Utica mutations appear thus in the interval between the earliest and last known occurrences of the species.

**Order Trepostomata**

**Family Monticuliporidae** Nicholson (emend. Ulrich)

**Genus Aspidopora** Ulrich

*Aspidopora bellula* Ulrich and Bassler MS

Plate 10, figure 3

This, as yet undescribed species was recognized by Doctor Ulrich in material from station 17 of the Lorraine gulf section. It is found
there at stations 15 to 19 and is also very common at station 4 of the Wood creek section. Doctor Ulrich informs us that in Ohio it occurs near the top of the Economy or base of the Southgate member of the Eden. In New York it seems to be restricted to the base of zone 2, corresponding to the basal Southgate beds.

The small thin calotte-shaped expansions will be fully described and figured in a forthcoming publication by Doctors Ulrich and Bassler. It may therefore suffice here to figure the species identified by Doctor Ulrich, to show the general form and appearance of the zoarium.

**Aspidopora sp. nov.**

Plate 8, figure 7

The Pulaski shale at Pulaski, below the railroad bridge, has furnished small zoaria, consisting of free, subcircular expansions about 7 mm in diameter and 2.5 mm thick. The internal structure is destroyed by the coarseness of crystallization to such an extent in the specimens that their structure could not be determined more accurately than to make probable the position of the form in the genus Aspidopora. There are no Maysville species as yet described of that genus and our form does not seem to belong to any of the three Eden species, although in size and shape of zoarium closely approaching to *A. eccentrica* (James). The zooecia are, however, twice as small in the Pulaski form (4 to 6 in 1 mm) and mesopores seem to be rare.

**Genus Prasopora** Nicholson and Etheridge

**Prasopora cf. contigua** Ulrich

The upper Utica shale at Holland Patent, N. Y., has afforded the zoarium of a small hemispheric Prasopora, 14 mm in diameter, but with the larger and central portions of the zoarium broken out so that no thin sections could be made. Doctor Ulrich considers the species as closely related to his *P. contigua*, a Black river (Decorah) form of Minnesota, which in turn is again closely related to *P. simulatrix*, well represented in the Trenton of New York by *P. simulatrix orientalis*. The zooecia are quite small in the specimen, numbering 11 in 3 mm as in *contigua*. We consider it quite possible that this small Prasopora is a derivative of the larger Prasopora of the Trenton limestone, dwarfed by the unfavorable facies.
Genus *Peronopora* Nicholson

*Peronopora* cf. *compressa* (Ulrich)

An impression of a fragmentary expansion of a bryozoan zoarium found in the Lorraine shale exposed in Lorraine village has been determined by Doctor Ulrich as a *Peronopora* comparable to *P. compressa*, a Maysville (McMicken) species of the region of Cincinnati. The specimen was found in a bed filled with *Crypтолитус lorrainensis* and is of late Eden age; it is not sufficient for conclusive determination.

Family **Heterotrypidae** Ulrich

Genus *Dekayella* Ulrich

*Dekayella ulrichi* (Nicholson)

*Dekayella ulrichi* was recognized by Doctor Ulrich as the bryozoan which at station 20 of the Lorraine section fills a thin limestone band.

The species was first described by Nicholson (1874, p. 504, 1875, p. 197) who at first identified it with the *Chaetetes fletcheri* of Milne-Edwards and Haime, but later (1881, p. 131) proposed the specific name for it which it now bears. Ulrich has later (1883, p. 91) brought it under his genus Dekayella, which, however, it is contended by Cumings (1908, p. 744) is identical with Dekayia M. E. & H. and Heterotrypa, Nicholson.

Cumings (1908, p. 824) and Bassler (1906, p. 35) have furnished more elaborate descriptions noting the interior characters.

Bassler (1906, p. 35) states that *D. ulrichi* is "a characteristic and exceedingly common fossil in the Eden shale of most localities in the Ohio basin." It no doubt also ranges through a greater thickness in our Whetstone gulf formation than the occurrences here recorded would indicate. Foerste (1916, p. 195) has observed this species in the Nicolet river section in Quebec and about Toronto, Meaford, and on Manitoulin island in Ontario. It was hence, in Eden time well established north and northwest of the Ohio basin region.

Genus *Stigmatella* Ulrich and Bassler

*Stigmatella irregularis* (Ulrich)

Plate 10, figures 1 and 2

Small irregularly spherical zoaria that are extremely common at certain horizons of our Lorraine shales have been identified by
Doctor Ulrich with his species *Stigmatella irregularis*. This was first described as *Chaetetes irregularis* (Ulrich, 1879, p. 129) and later by Ulrich and Bassler (1904, p. 34) referred to their new genus Stigmatella.

The genus is, according to its authors, characterized by the periodic thickening of the walls (see text figure 70) of the zooecial tubes and the accelerated development of the acanthopores in these thickened zones. At the same time the diaphragms are but sparsely developed.

Bassler in his Bibliographic Index cites *S. irregularis* as occurring in the Bellevue member of the Maysville, at Hamilton, Morrow, Mason and Cincinnati, Ohio. In New York it is very common in a shale bed at station 14 (zone 3) of the Whetstone gulf section and has also been rarely observed at stations 17 (zone 3) and 22a of the Lorraine section (zone 4) and in the Pulaski formation at Pulaski below the bridge. The rare occurrences in the Lorraine section would indicate its appearance already in Southgate time while that in zone 5 corresponds to its western range.

**Stigmatella subsphaerica** nov.

*Text figures 69-71*

There occurs at station 12-13 of the Lorraine Gulf section (in the Whetstone Gulf formation), associated with *Amplexopora persimilis* Nickles, a *Stigmatella* that grew in irregularly subspherical masses, having a diameter of 24 mm or more, with fairly smooth surface and distinct maculae.

In thin sections the zoarium is seen to be composed of medium-walled angular zooecia, numbering 4 or 5 in 1 mm, and of numerous mesopores, which, however, are crowded in the maculae or spots and rare outside of them. Acanthopores not very numerous, but conspicuous. The walls of the zooecial tubes are of the same general thickness in the axial and mature regions, and possess zones of thickening by acanthopores. Diaphragms are far apart in the axial region, but become crowded in the mature region.

This species is distinguished from *S. clavis* Ulrich, another Eden form, by the presence of numerous mesopores in the maculae, from *S. nana* Ulrich and Bassler by its mode of growth. It is not seemingly identical with any of the Maysville species.
Figures 69–71 Stigmatella subsphaerica nov. Figure 69 Transverse section; figures 70, 71 Longitudinal sections. x15.

Figures 72, 73 Stigmatella pulaskiensis nov. Transverse and longitudinal sections. x15.

Stigmatella pulaskiensis nov.

Text figures 72 and 73

Stigmatella pulaskiensis grows in irregular free, subhemispherical to club-shaped zoaria attaining a diameter of 20+ mm and an equal length.

In thin section the species appears to be most closely related to S. dychei (James). Like the latter (Bassler, 1906, p. 54), the Pulaski form is distinguished by the thin walled angular zooecia with mesopores practically wanting and the development of acanthopores in zones and the scarcity of diaphragms. There is, however, no direct evidence that S. pulaskiensis was encrusting
as the McMillan form and the diaphragms are not almost entirely absent as in S. d y c h e i but found in widely separated zones, which are more or less associated with the equally widely separated zones of acanthopores, appearing as thickenings in the walls of the zooecial tubes.

The size of the zooecia is the same as in S. d y c h e i, our material showing about five tubes in 1 mm.

The species occurs in the calcareous intercalations with Climacograptus lorrainensis, in the Pulaski beds at Pulaski, N. Y. Types from United States National Museum collection (no. 10184).

**Stigmatella** sp. nov.

Plate 8, figures 5 and 6

The Whetstone gulf formation contains at station 12–13 of the Lorraine gulf section, a new form of Stigmatella, which, according to Doctor Ulrich, occurs also in the Southgate shale at Cincinnati, and will eventually be described with the new Cincinnati material.

We have figured a zoarium, attached to a crinoid stem and illustrating a common occurrence of the form.

**Genus Atactopora** Ulrich

**Atactopora hirsuta** (Ulrich)

Plate 10, figure 5

For original description see Ulrich (1879, p. 120).

The genus, which is represented by but two species is characterized by “the incrusting zoaria, with the subsolid elevated maculae and the numerous small acanthopores inflecting the zooecia.”

Although, in the Lorraine formation, this species has been observed only in casts of the exterior, the calcareous substance of the incrusting zoaria, as well as that of the cephalopod shells having been dissolved in the sandstone, the irregularly arranged maculae and the granular surface leave no doubt of its presence. Some of the incrusting zoaria reach a very large size, diameters of 70 mm and more having been observed.

It is found in the Pulaski formation at Pulaski and in the drift material, attached to various cephalopods, as Paractinoceras lamellosum in the case of the specimen figured. In the west it occurs in the Eden and Maysville (Fairview) at Covington and Newport, Ky., and Cincinnati, Ohio.
Atactopora maculata (Ulrich)

This species which differs from the preceding mainly in bearing upon the superior edges of the tube walls, when well preserved, a few small spines instead of the numerous minute granules of A. hirsuta, is probably also present among the parasitic bryozoans of the Lorraine, although on account of the preservation of the material, it is not always possible there to distinguish with certainty between the two species.

There occur, however, incrustations, which besides the solid monticules are smooth enough to represent this species.

A. maculata is a Maysville (Fairmount) form of Cincinnati, Ohio, and it has also been found by Foerste (1916, p. 73) near Toronto, Ontario.

Genus Leptotrypa Ulrich

Leptotrypa minima (Ulrich)

Plate 10, figure 4

For original description see Ulrich (1883, p. 159).

The aspect of the longitudinal and tangential sections, has been elaborately described by the author of the species. Since only the impression of the exterior is preserved in the Lorraine sandstone, the interior structure of the zoaria can not be studied, but the aspect of the exterior, with its small, but high, regularly spaced monticules and outlines of minute, thin-walled, angular zoecia leaves no doubt of the identity of the Pulaski form incrusting upon Actinoceras crebrisep tum and other cephalopods, with the species that in the Maysville (Bellevue) of Hamilton, Ohio, is found incrusting upon Orthoceras.

Family Batostome l l i d a e Ulrich

Genus Bythopora Miller and Dyer

Bythopora arctipora (Nicholson)

Plate 9, figures 5 and 6

Bythopora arctipora was described by Nicholson (1875, p. 180) as Ptilodictya ? arctipora.

The internal structure of the zoarium has been shown by Bassler (1906, pl. 2 figs. 1 and 2).

Bythopora arctipora is according to Bassler a characteristic and very abundant fossil of all divisions of the Eden shale in the Ohio basin and Foerste has likewise found it in the
Eden of western Ontario, near Toronto and on Manitoulin island. In New York it occurs at stations 4 and 9 of the Wood creek section and at stations 18, 19, 20a and 21a of the Lorraine section and at Lorraine village, in some beds in profusion. It is here, apparently restricted to the upper part only of the Whetstone Gulf formation.

**Bythopora gracilis** (Nicholson)

*Bythopora gracilis*, a common Maysville bryozoan, has been described and figured by many authors. The first description with illustration was furnished by Nicholson (1874, p. 504; 1875, p. 198) who as *Chaetetes gracilis* credited the species to James (1871, p. 3).

Cumings (1908, p. 782) has materially elaborated the earlier description.

Bassler (1906, p. 21) records this species as being abundant in both the Fairview and MacMillan divisions of the Maysville throughout the Ohio basin, and especially abundant in the Corryville member. Ulrich (1889, p. 35) has also recognized it in material from Stony mountain, Manitoba, and Foerste (1916, p. 195) has found it in Ontario West about Toronto and on Manitoulin island. In New York we found it (an early form, *fide* Ulrich) very common in a block filled with Cryptolithus obtained loose in Lorraine village, as well as in many drift boulders from the Pulaski ferruginous sandy limestone. It is also very common in the outcrops at Pulaski at stations 13a and 16; in the former in association with *Stigmatella irregularis*; on sandstone slabs in the Museum collection from the neighborhood of Rome (south of Rome?), and was collected by the writer as a common fossil at station 12 of the Wood creek section (small form of Fairmount member, *fide* Ulrich) and station 12 of the Whetstone gulf section; and found to occur more rarely at station 29 of the Lorraine section.

**Bythopora dendrina** (James)

*Bythopora dendrina* is a very little known bryozoan of the Maysville of the vicinity of Cincinnati. It was first described but not figured by James (1878, p. 3, 14) as *Helopora dendrina* and only a few days later more fully described and figured by Miller and Dyer (1878, p. 6) as *Bytho-
pora fruticosa. According to Bassler (1906, p. 20) both descriptions were based on the same specimen.

This species, which may be distinguished from its congeners by its frequently branching slender stems, occurs in the Fairmount member of the Maysville at Cincinnati, Ohio, and vicinity. The form here identified with it (fide Ulrich) was found abundantly at stations 25, 26, 27, 27a, 29, 30, 31, of the Lorraine gulf section; it thus is a characteristic fossil of the two uppermost zones (5 and 6) of this section.

Family Amplexoporidae Ulrich
Genus Amplexopora Ulrich

Amplexopora ? discoidea (Nicholson)

This common species of the Pulaski formation of New York was first adequately described and figured by Nicholson (1874, p. 511, 1875, p. 206).

It is, according to Bassler, (1906, p. 12) "readily recognized by its discoid habit of growth, absence of mesopores and by rather numerous acanthopores and diaphragms."

Amplexopora ? discoidea is a characteristic fossil of the Fairmount member of the Maysville at Cincinnati, Ohio, and vicinity. Nicholson had also recognized it in beds at Weston, near Toronto, but Foerste (1916, p. 73, 74) has not observed it there. In the Lorraine of New York the small disklike bryozoan is a common fossil in the Lorraine section at stations 24, 25, 27a and 31; the Whetstone gulf section at stations 12 and 14, the Wood creek station 13, at Pulaski above and below the bridge and in the drift material from the calcareous sandstone of the Pulaski formation.

Amplexopora persimilis Nickles

Plate 9, figure 2

The upper beds of the Whetstone gulf formation, corresponding to the Southgate division of the Eden, have furnished at station 12–13 of the Lorraine gulf section a branching form of Amplexopora, identical with Amplexopora persimilis Nickles (fide Ulrich). This species was recorded by Nickles (1905, p. 47) as occurring in the lower two-thirds of the Eden group of the Cincinnati region, but was restricted by Bassler (1915, p. 37) to the Economy member.
Foerste (1916, p. 86, 88, etc.) has since recorded its occurrence in beds of middle Eden age on Manitoulin island, western Ontario (Sheguiandah shale). *A. persimilis* appears thus to persist in both the Canadian and New York equivalents of the Eden into a later division in the Ohio basin.

This exceedingly abundant bryozoan exhibits considerable variations notably in the size of the zoarium and the size and number of the acanthopores.

**Amplexopora cf. petasiformis** (Nicholson)

Dr A. F. Foerste was so kind as to send me a fairly large bryozoan stock which he collected in the black shale at Allendale, at the mouth of the Lorraine gorge, and which is principally interesting on account of its occurrence in this graptolite shale (Deer River shale). The form is placed by Doctor Ulrich near *Amplexopora petasiformis*, a characteristic Eden species (Economy-McMicken) of the Cincinnati region.

The Allendale specimen, which comes from beds approximately homotaxial to the Economy shale of Ohio, has a subconical massive zoarium, like the common *Prasopora simulatrix orientalis* of the Trenton, about 50 mm in diameter and originally at least as high. It is hence larger and relatively higher than the typical *A. petasiformis*. The surface shows numerous monticules, about 2.5 mm wide and polygonal zooecia, numbering 3 to 5 in 1 mm with clusters of large zooecia, the zooecia surrounded by numerous small acanthopores. In tangential section it is seen that the walls are thin and delicate, as in *petasiformis*, and that small mesopores are present. Diaphragms horizontal, not nearly as numerous as in *A. petasiformis* (Nicholson 1881, p. 130, f. 40; Cumings 1908, pl. 6, fig. 3a).

**Family Halloporidae** Bassler

**Genus Hallopora** Bassler

**Hallopora onealli** (James)

*Hallopora onealli* was first described but not figured by James (1875, p. 2) as *Chaetetes onealli* and later currently referred to the well-known genus Callopora Hall. Lately, however, Bassler (1911, p. 325) has replaced this generic term by Hallopora, the older one having been preoccupied.

The species has been fully described by James and Nicholson (1881, p. 118).
The aspect of James's types has been made known by Bassler (1906, pl. 6, figs: 1, 2) and Cumings has furnished excellent figures of the surface as well as of transverse and longitudinal sections.

According to Cumings, *H. onealli* is common only in the lower member (Economy) of the Eden shales, though found sparingly at higher levels. Bassler cites it from the Economy bed at Cincinnati, Ohio, and vicinity. The writer has recorded it (1912, p. 51) from the Indian Ladder beds, and Foerste (1916, p. 90) has collected it on Manitoulin island. In the Whetstone Gulf formation of New York it is present at station 5 of the Wood creek section, where it fills a shaly layer. This occurrence as well as that at the Indian Ladder corresponds in age to the lower Southgate. It also occurs there at section 1 of the Wood creek section (zone 1 or Economy member) and probably at other outcrops of this zone.

**Hallopora onealli var. sigillarioides** (Nicholson)

This species was described by Nicholson (1875, p. 203) as *Chaetetes sigillarioides*, but it is now only considered a variety of the longer known though less common *H. onealli* (James), being mainly distinguished by its larger size. Cumings (1908, p. 790) suggests that under favorable conditions of growth (nourishment, temperature, clearness of water etc.) the stems become larger (*sigillarioides*) and under unfavorable conditions they grow smaller (*onealli*).

According to Nicholson, the stems are as a rule more than 2 mm thick; (4-5 mm, Bassler); the zooecia are regularly oval or subcircular, arranged in diagonal lines, about 6 in 2 mm, measured diagonally and from 4 to 5 in the same space, measured vertically. Few minute mesopores are visible between the zooecia, and the walls of the latter are thin. Even fragments of this species can, as a rule, be recognized by the presence of the opercula with their circular opercular foramen which opercula though a generic character, are perhaps rather more frequently seen in this species than in any other. These perforated opercula are due to the formation of perforated diaphragms over the mouths of the zooecia, as Nicholson suspected.

**Hallopora onealli sigillarioides** is common throughout the Eden shale from the Economy to the McMicken member in the Cincinnati region, as well as in Indiana (Cumings). Foerste (1916, p. 197) has also found it in Quebec (St Augustin) and in various outcrops on Manitoulin Island, all in beds of Eden age.
In our material from the Whetstone Gulf formation the species was recognized by Doctor Ulrich in a collection from station 1 of the Wood creek section (zone 1). It is also found at stations 6, 8 and 9; at 6 as a very common and large fossil. It further occurs in the Moose creek section at station 11-12; and in the Lorraine section at station 17. It thus ranges in the New York rocks throughout the Whetstone gulf formation, but does not pass beyond it.

**Hallopora andrewsi** (Nicholson)

Plate 9, figure 1

*Hallopora andrewsi* was first identified by Nicholson (1874, p. 503) with *Chaetetes pulchellus* Milne-Edwards and Haime, but subsequently (1881, p. 128) recognized as a new species (*Monticulipora andrewsi* Nicholson). It is known from the Bellevue and Corryville members of the Maysville from Cincinnati and vicinity, and from southeastern Indiana. It has been recognized (*fide* Ulrich) in the collection from station 22a of the Lorraine section; and is of some importance in drawing the boundary line in that section between the MacMillan and Fairview divisions of the Maysville, since it does not seem to descend into the latter division in the Ohio basin. It is preceded in our Lorraine sections by the similar Eden form *Hallopora onealli sigillarioides* (Nicholson).

It has been fully described by Nicholson and by Cumings (1908, p. 785).

**Family Trematoporidae** Ulrich

**Genus Hemiphragma** Ulrich

**Hemiphragma bassleri** nov.

Plate 9, figures 3 and 4

The upper Utica shale at Holland Patent contains a large bryozoan whose zoaria consist of rounded somewhat club-shaped stems that bifurcate once or twice. In habitus this form is comparable to *Hemiphragma tenuimurale* Ulrich, a western Trenton (Prosser) species and to *H. whitfieldi* (James) an Eden (Economy, Southgate) species of the Cincinnati region, though coarser than either (diameter of stems 6-11 mm). The surface is as in the latter species, but with more sparsely scattered maculae; the zooecia are large, rather thin walled, polygonal as in *H. whitfieldi* numbering about 5 in the space of 2 mm. The specimens
are pyritized throughout, but show the zooecial structure well on being fractured. It is seen on these fractures, that the zooecial walls are very thin, as in the Eden species; and furnished with diaphragms, that partly are incomplete, though not nearly in such prevailing number as in the two above-mentioned species. Nor is, in vertical sections, the zooecial wall in the axial regions as distinctly crinkled, as Bassler (1906, p. 41, pl. 2, fig. 15) describes and figures this important character of H. whitfieldi. Mesopores are small and angular, and few in number. Acanthopores, which are absent in the two other species cited here, but present in the Galena species H. ottawense (Foord) and H. irrasum Ulrich are also seen on the surface.

The form is therefore probably new and may be known as H. bassleri.

Order Cryptostomata

Family Arthrostylidae Ulrich

Genus Arthrostylus Ulrich

Arthrostylus tenuis (James)

First described by James (1878, p. 3) as Helopora tenuis from the lower Cincinnatian, this species has later been placed by Ulrich (1895, pl. 3, fig. 16e) in his genus Arthrostylus. Bassler (1906, p. 16) has fully described it.

Ulrich, who first gave a correct account (1882, p. 160) of this fossil, states that he had before him specimens which preserved several hundred of the small segments still in connection.

This species occurs in the upper Trenton and Eden of Cincinnati, Ohio, and vicinity, where it is especially abundant in the Economy beds. It was also recognized by Doctor Ulrich in a collection from the Indian Ladder beds near Albany, N. Y., (Ruedemann, 1912, p. 51) and is found in good preservation in the material from the Triarthrus bed of the Frankfort shale at Six Mile creek near Rome, N. Y.

Family Ptilodictyonidae Ulrich

Genus Arthropora Ulrich

Arthropora cincinnatiensis (James)

This, the Ptilodictya ? cincinnatiensis of James (1881, p. 39) agrees, according to Bassler (1906, p. 14) most nearly in growth with A. cleavelandi; but “may be distinguished by its smaller, nearly cylindrical and proportionally stouter branches,
while in zooecial structure it differs in having decidedly broader interzooecial spaces, causing the zooecial apertures to be much smaller."

It is a Maysville (Mount Hope) species of Cincinnati and vicinity. We have found the species well represented in shale several miles below Pulaski (our zone 3), but also in Pulaski beds above the bridge at Pulaski.

**Arthropora shafferi** (Meek)

**Arthropora shafferi** was first described but not figured by Meek as *Ptilodictya (Stic topora) shafferi* in 1872 (p. 317) but later (1873, pl. 5 figs. 1a–c) also figured. It was made the genotype of his genus *Arthropora* (1882, p. 167) by Ulrich, who also furnished new figures.

According to Bassler (1906, p. 14) this species agrees with *A. cincinnatiensis* "in the external appearance of its zooecia, but differs decidedly in the greater size of its segments and in their broader, relatively shorter, more frequent, and compressed lateral branches."

It is a Maysville (Bellevue and Corryville) form of Cincinnati, Ohio, and many localities in Indiana, Kentucky, and Tennessee (Bassler), and occurs also in the Don valley near Toronto, Ontario (Foerste, 1916, p. 73). We have found good specimens at stations 24, 27b and 28 of the Lorraine sections (lower and middle Pulaski formation), and at station 13 of the Wood creek section.

**Arthropora cleavelandi** (James)

**Arthropora cleavelandi** (James) is a very common fossil in many of our lower Lorraine outcrops.

It was first described, but not figured by James (1881, p. 38) and has since been figured and discussed by Bassler (1906, p. 15). From these authors we learn that it is a characteristic representative of the genus *Arthropora*, a genus of bifoliate bryozoans characterized by its regularly and frequently jointed zoaria. The segments of these zoaria are slender and generally nonbifurcating, the complete zoarium probably having consisted of only a few rigid branches. Only separate segments have been found in our rocks, and according to Bassler, specimens retaining more than a sequence of two or three are extremely rare. The average length of a segment is 7 mm. The segments are flattened, celluliferous on
both sides, and characterized by the numerous and small lateral branches springing out at nearly right angles from the main stem. The basal segment, which has not been seen in our material, is bifurcated and drawn out acuminately below.

Bassler, in his authoritative Bibliographic Index, cites the species as occurring in the Eden of Cincinnati and vicinity. Foerste (1916, p. 86, 91, 92) has also observed it in several localities upon Manitoulin island, western Ontario. In New York we have found it at station 20 of the Lorraine section, stations 5, 7 and 9 of the Whetstone gulf section; and 1, 3, 4, 9 and 10 of the Wood creek section, all zones of the Whetstone gulf formation.

Genus **Escharopora** Hall

**Escharopora pavonia** (Milne-Edwards and Haine)

*Escharopora pavonia*, one of the most common bryozoans of the Maysville of Ohio, is currently credited to D'Orbigny. According to Cumings (1908, p. 832), however, d'Orbigny's type is a Peronopora and the form was first described by Milne-Edwards and Haine (1851, p. 267) as *Chaetetes pavonia*. This species, owing to its large zoaria and common occurrence, has been described and figured by many authors, notably Nicholson (1874, p. 509; 1875, p. 209), Bassler (1903, pl. 20, figs. 3 and 4) and Cumings (1908, p. 832). From these authors we learn the following facts:

The zoarium forms a broad, thin, undulating, vertical expansion, often of considerable extent, but only 2 to 3 mm thick. The expansion consists of two layers of zooecia, which open on opposite sides of the zoarium. The zooecia are subequal, oval or pentagonal, often arranged in decussating lines, and elevated at intervals into low and inconspicuous monticules. They average about 10 in 2 mm and 7 in the maculae and become thick-walled through secondary deposits. The tabulae are few and far apart.

Bassler (1915, p. 500) recorded the form as occurring in the Maysville (Fairmount) of Cincinnati, Ohio, and vicinity and in the equivalent Leipers beds of central Tennessee. In the Lorraine group of New York it was found at station 12 of the Whetstone gulf section, where it forms a thin limestone layer, and is associated with other Fairmount species in the surrounding shale. It is also fairly common in the drift material of ferruginous sandstone from the Pulaski formation.
Family Rhinidictyonidae Ulrich
Genus Rhinidictya Ulrich

Rhinidictya *cf.* parallela (James)

The Indian Ladder beds have afforded a small fragment of a Rhinidictya which Doctor Ulrich compared with *R. parallela*, an Economy species of Cincinnati. The specimen is however too imperfect for positive determination or to invite further notice.

Family Palescharidae Ulrich
Genus Paleschara Hall

Paleschara *beani* (James)

Text figure 74

This species, originally described and figured by James (1878, p. 5 and 1884, p. 23, fig. 3–3b) as *Ceramopora ? beani*, has been referred to Paleschara by Ulrich (1888, p. 186).

The zoarium of *Paleschara beani* is described as encrusting whole shells of Orthoceras in the Richmond (Waynesville) beds of Ohio. The zooecia “are arranged in a somewhat quincuncial order in alternating oblique rows; but in other cases they are not so regularly disposed.” They are elongate polygonal (quadangular to hexagonal), as a rule twice as long as wide and in typical development rhombic with truncated ends. The cell walls are relatively thin and low. The zooecia number 9 to 12 in 5 mm counted in the direction of their major axes and not quite twice as many measured in the other direction.

Figure 74 *Paleschara beani* James. Zoarium x10.
Doctor Bassler has pointed out (1906, p. 46) that the important feature, not mentioned by James, is that unlike all other similar Ordovician bryozoa maculae, or clusters of larger zooecia or of mesopores are absent. “In this peculiarity, as well as in all other features, the species is in accord with Paleschara.”

Bassler’s Bibliographic Index (1915, p. 942) cites *Paleschara beani* only from the Richmond of Ohio, as noted before, and mentions that in the original description James erroneously cites the species from Cincinnati. It would seem, however, that the material of Paleschara from the Eden can not be separated by any discernible differences, either in shape or size of the zooecia from the Richmond representatives. We have before us fine specimens, encrusting shells of Orthoceras and Liospira, from the lower Lorraine (Whetstone Gulf formation), 1½ miles east of Rome, N. Y. (No. 23545 United States National Museum) that have been identified by Doctor Bassler with *Paleschara beani*. We have also collected this species at station 1 of the Wood creek section (zone 1 of Whetstone Gulf formation) in beds corresponding to the Economy of the Eden, and seen it in material of the same age in the Rust collection in the State Museum from the neighborhood of Rome and identical with the material in the United States National Museum.

**Class Brachiopoda**  
**Order Atremata**  
**Family Obolidae King**  
**Genus Leptobolus Hall**  
**Leptobolus insignis** (Hall)

*Leptobolus insignis* is described by Hall (p. 227) as occurring in the Utica shale at Middleville in Herkimer county; near Fort Plain; at Utica, and other places in New York. It is also known from the contemporary Fulton shale at Cincinnati and from the Utica shale at Ottawa and Anticosti (Macastty shale). The writer has before (1912, p. 16–61) found it in the Canajoharie, Schenectady and Snake hill shales of Trenton age. Likewise it was found to pass, in a mutation, and with its most common associate, *Triarthrus eatoni* into the lower Lorraine (Whetstone Gulf) formation; in the Lorraine section to stations 4 and 7 and in the Whetstone gulf to station 7, all belonging into zone 1 (Economy horizon). In the shale facies it ranges therefore in New York from the Trenton into the lower Lorraine.

This species has been fully figured by Hall & Clarke in Palaeontology of New York, volume VIII, part 1, plate 3, figures 1–6.
Leptobolus insignis mut. latus nov.

Plate II, figures 15-16

The specimens of L. insignis of some of the post-Utica beds when compared with the typical representatives of the species from Holland Patent and Utica show a tendency to be broader posteriorly, the cardinal line forming a less acute angle.

In the characteristic specimen here figured this angle is about 130°, while in Hall’s figures (1872, pl. 7, fig. 17), (Hall and Clarke, 1892, pl. 3, fig. 3) it is only 100°. It is true one finds also such obtusely pointed shells in the Utica material, but they are not dominant as in the later faunas. Likewise the radiating striae are more likely to develop into coarser ribs, similarly as in Leptobolus walcotti, which this mutation also approaches in outline. These coarser ribs seem to have grown into short projecting mucros along the frontal margin.

The specimen here figured is 2.2 mm long and 2.1 mm wide. It came from the Deer River shale at the Allendale bridge at the lower end of the Lorraine gulf.

The United States National Museum contains a series of well-preserved specimens of this mutation from the Frankfort shale at Six Mile creek near Rome, N. Y. These specimens, when compared with the material from the Utica shale, are not only distinctly more rounded and broader posteriorly, but also larger by one-third than the average of the Utica specimens (2.1–2.5 mm as against 1.5–2 mm). At the same time, the smaller Utica specimens appear to have had much thicker shells and to be less compressed, or originally to have been more convex. This difference may be apparent and due to the different composition of the matrix, the somewhat calcareous Utica shale retaining the shells of this Leptobolus, while in the purely argillaceous Frankfort shale all shell substance is dissolved.

To Leptobolus may also belong the cast of the interior of the pedicel valve here reproduced in plate II, figure 16. It shows strong scars of the central and lateral muscles, different from those seen in Leptobolus insignis, but similar to those shown in species of Lingu'a, Lingulops and Obolus fimbriatus Hadding (Hadding 1913, pl. 5, fig. 11).

The latter is one of the vicarious forms of our species of Leptobolus in the Swedish graptolite shales, figured by Hadding.

It is possible that a stronger development of the fulcra of the laterals than seen in the typical Leptobolus insignis may lead to the development observed in this specimen.
Doctor Foerste (1914, p. 255, pi. 3, fig. 13) has described and figured a Lingula from the Pulaski beds (Trinucleus beds at Pulaski, N. Y., without naming the species. He states:

At the Trinucleus horizon, several hundred yards west of the railroad bridge, about a mile east of Pulaski, a species of Lingula occurs which is distinct from Lingula rectilat eralis. It is smaller and slightly less quadrangular. If lines are drawn from the beak to the anterolateral angles, the concentric lines are much more conspicuous on the lateral parts of the shell than on the intermediate portions. The shell is very thin and there is no indication of longitudinal radiating striae along the middle parts of the shell, either on the exterior or interior surfaces. The shell apparently belongs to the group with a long median septum and with concrete laterals, such as are figured by Hall, and Clarke (1892, Plate 1, fig. 7) under the name Lingula proct eri.

Another Lingula has been collected by the writer at station 13 of the Whetstone gulf section, belonging to zone 2, (Southgate) of the lower Lorraine or Whetstone Gulf formation. This is elongate ovate, its width (8 mm) to its length, (11 mm) approximately as 2 to 3; widest in the anterior third, the anterior margin well rounded; sides gently convex, converging from the point of greatest width, to the acutely rounded beak. Surface with lamellar striae which are coarser on the sides, while the median portion is fairly smooth excepting two faint divergent sulci. The impression of a median septum is indicated in the matrix where the shell is broken away in the posterior portion.

This species recalls in the sulci Lingula bisulcata Ulrich, an Economy form which however is wider and differs in outline. In outline, this species approaches L. proct eri, a Trenton form.

Lingula bisulcata Ulrich

Plate 11, figures 3 and 4.

Ulrich's species (1889, p. 380) is based on a specimen found in the Economy beds of the Eden at Ludlow, Kentucky. The specimen here identified with it, came from the lower Lorraine (Whetstone Gulf) formation near Rome and is from the Rust collection. It is preserved in a dark shale and in an association that indicates a similar horizon as that of the type of the species. Its outline completely agrees with that of the western form, although its size
is only half that of the latter. The faint diverging sulci extend to the angles and the fine radiating lines are visible only near the anterior region.

**Lingula (Pseudolingula) rectilateralis** Emmons

Plate 11, figures 1 and 2

The large Lingula passing under the name of *Lingula rectilateralis* was first figured without being described by Emmons (1843, p. 399) as being associated with *Triarthrus becki* in the shales of Jefferson county, and thus belonging to the Utica shale as he conceived it. Hall (1847, p. 286) does not recognize Emmons's species, but referred it to his *Lingula quadrata* Eichwald, which he had described from the Trenton limestone, stating that he could find no more deviation than is often observed in the same shell in the limestone. Emmons does not seem to have accepted this determination for he records (1855, p. 201) *Lingula quadrata* as a Trenton limestone fossil only without, however, mentioning *L. rectilateralis*. Hall and Clarke (1892, pl. 7, fig. 13) have figured a Trenton type as *L. quadrata* (Eichwald) Hall, while subsequently Schuchert (1897, p. 253) united the Trenton and Lorraine forms under *L. rectilateralis* Emmons, stating this species to be more closely related to *L. iowensis* than to *L. quadrata* Eichwald. The writer (1912, p. 91) has figured and annotated a representative of this species from the Schenectady beds, thereby erroneously stating that Hall had recorded the species from the Trenton only. It appears from Foerste's remarks (1914, p. 255) that he is inclined to recognize the Trenton and Lorraine forms as distinct types and Bassler (1915, p. 733) records *L. recti¬lateralis* as occurring only in the Utica at Rodman, Lorraine etc. in New York, citing, however, in the synonymy also Hall's description and figures of the Trenton form, and thus evidently intending to include the latter under the heading of *L. recti¬lateralis*. Bassler is obviously influenced by Foerste's statement that Emmons's remark that *L. recti¬lateralis* is associated with *Triarthrus becki* and the black color of the rock in which Emmons's type in the American Museum of Natural History is preserved, indicate that Emmons's types came from the black shale at the mouth of the Lorraine gulf currently referred to the Utica.

We have failed to find specimens of this species in place, but have before us several topotypes or specimens from Emmons's
original locality, Rodman. These are preserved in a very dark gray, coarse-grained shale, such as occurs in the Deer River shale at Allendale, but also in frequent intervals in the succeeding zone of the lower Lorraine shale (Whetstone Gulf formation). Since, moreover, *Triarthrus eatoni* is shown in this paper to range very high up in the Whetstone Gulf shale, it is also possible that the specimens came from the first zone of the Whetstone gulf. The fossils, associated with the Lingula, small Primitias, are not of a character to determine the age.

Foerste (op. cit. p. 255) gives the following description of the original of Hall's figure 1a on plate 79:

In Hall's specimen the anterior is rounded. Radiating lines fine and numerous, successively finer towards the sides of the shell. Apparently with a strong median septum and with cuneate concrete laterals, the anterior part of the middle pair corresponding to the centrals as in the group of shells including the one erroneously identified by Hall as *Lingula quadrata*, also *L. cincinnatensis* and *L. iowensis*.

A comparison of the Trenton form of "*rectilateralis*" with the specimens from Rodman indicates that while the general outline, notably the proportion of length to width (3:2) is the same, the Lorraine specimens attain only half the size (about 20 mm) of the Trenton type and show a more distinct tendency to parallelism of the lateral margins, which in most cases become even slightly concave in the middle. It also seems that the Lorraine specimens are less convex than those from the Trenton or the Schenectady beds; this however, may be due to the preservation in a softer shale and the resulting greater compression. The difference in relative size and outline, coupled with the larger one of age, appear sufficient to distinguish the Trenton form as a mutation from *L. rectilateralis*, for which we propose the name *major*.

**Lingula progne** Billings

*Lingula progne* was originally described by Billings (1865, p. 47) from the Collingwood ("Utica") shale of Collingwood, Ontario, and the Trenton limestone of Montreal. It is characterized by its elongate oval outline, its width being about three-fifths of the length; its straight or very gently convex sides; a depressed zone extending from the beak to the front margin; fine crowded, concentric striae and longitudinal radiating lines.

The pedicle valve is somewhat pointed at the beak, while the brachial valve is obtusely rounded.
This species is present in the Utica shale (Herkimer etc.) and Frankfort shale (Rome) of New York, and possibly also in the lowest Lorraine (Whetstone Gulf) shale near Rome (no. 23546 United States National Museum). It is the form, in which Walcott (1888, p. 480) discovered the fleshy peduncle (Lingula aequalis Walcott, non Hall).

**Lingula curta** Conrad

*Lingula curta* has been cited by Hall (1847, p. 97) and subsequent authors as a fossil of the middle Trenton and Utica shale. It is, however, certain that this species occurs, besides the Trenton limestone only in those black shales of the Mohawk valley and regions to the northeast and southeast, which are of Trenton age, as the Canajoharie shale, Snake Hill shale, etc. In these it is a very common fossil, (Ruedemann, 1912, p. 26, ff. 61; Bassler, 1915, p. 727).

**Lingula cf. procteri** Ulrich

A small slab of dark gray sandy and micaceous clay shale, obviously from the lower Whetstone Gulf formation, at a locality “8 miles north of Rome, N. Y.” and now in the United States National Museum (no. 34515), bears a small Lingula that recalls *Lingula progne* Billings, a form of the Collingwood shale of Canada, and *L. procteri* Ulrich, from the upper Trenton of Kentucky, in its narrow posterior portion. In general outline, especially the rounded anterior margin it would seem to be closest to *L. procteri*, to which species it may be referred lacking sufficient material for closer determination.

**Order Neotremata**

**Family Trematidae** Schuchert

**Genus Trematis** Sharpe

*Trematis millepunctata* Hall

Plate 11, figures 22 and 23

*T. millepunctata* is a species that was described by Hall (1872, p. 221) from the “Hudson river group” of the Cincinnati region. It is there now known to range from the Eden to the Richmond, but has not yet been recorded from the rocks of the State of New York, where it has been found by us in zone 1 in the Whetstone gulf section, Wood creek section, and it appears as a common fossil in a station in the village of Lorraine. The
United States National Museum also contains specimens from the Whetstone Gulf shale of Totman gulf near Lorraine, N. Y.

Specimens from the village of Lorraine attain a length of 15 mm and a width of 17 mm, and do not exhibit any characters suggesting varietal differentiation from the western representatives. The species has been very fully figured and its interior structure made known by Hall and Clarke (1892, pl. IVG, figs. 4-10).

**Trematis crassipuncta** Ulrich

Plate 11, figures 24 and 25

For original description see Ulrich (1889, p. 22).

It occurs in the Fairmount beds of the Maysville group, in the neighborhood of Cincinnati. We have before us a very fine representative of this species, from station 22a of the Lorraine gulf section, just below Worthville, and belonging to zone 5.

Our specimen is 14 mm wide and 11 mm long. There are about fourteen lines of punctae to 5 mm in the lateral region. A portion of the valve is exfoliated at the right lateral side and the rows of punctae show as rows of tubercles on the inner surface.

**Trematis (?) sp. cf. dyeri** Miller

The collection of Frankfort shale fossils from Six Mile creek near Rome in the United States National Museum contains two fragments which have been designated by Professor Schuchert as "**Trematis** n. sp. near **T. dyeri**." They are the anterior portions of phosphatic shells marked by concentric lamellae such as are described and figured by Miller (1874, p. 347) for his species **dyeri**.

The latter is recorded by Bassler (1915, p. 1280) as occurring in the Fairmount bed of the Maysville and thus not so greatly differing in age from the Frankfort species that specific identity would be improbable. The fragments are, however, too imperfect to allow any conclusive determination.

**Genus Schizocrania** Hall and Whitfield

**Schizocrania filosa** (Hall)

This species, originally described by Hall from the Trenton limestone of New York, is now known to occur not only in the Trenton from New Jersey to Minnesota and Ontario, but also in the Maysville and Richmond of Cincinnati and vicinity and in Anticosti (Bassler, 1915, p. 1144).
In New York it has also been observed in the Utica shale, especially the upper division at Holland Patent and Steuben valley, in the Frankfort shale at Six Mile creek near Rome and in the Pulaski formation (Foerste, 1914, p. 9).

It has been fully figured by Hall and Clarke (1892, pl. 4G, figs. 22-30).

Family Siphonotretidae Kutorga
Genus Schizambon Walcott

Schizambon minutus nov.

Plate 11, figures 18-21

Two fragments of the test of a eurypterid from the upper Utica shale at Holland Patent, N. Y., in the United States National Museum, were found covered with a minute form of a Schizambon in such numbers, that a piece not over half a square inch in size, bears no less than fifty-six specimens. These are all so uniform in size and characters on both fragments, that the possibility of their being an early growth stage of a larger form such as Schizambon canadensis seems excluded, and we consider them as representing a new species.

Description. Shell minute (largest diameter 1 mm) subcircular to transversely ovate, moderately convex; apex anteriorly of the beak. Ventral valve with small, circular foramen situated on or just in front of apex. In the dorsal valve the beak is marginal, hardly projecting beyond the margin. The interior of the dorsal valve shows a short median septum and two curved ridges indicating the narrow main vascular canals.

Surface with fairly widely spaced growth lines separated by smooth interspaces; each growth line produced into a fringe of straight, hairlike spines of uniform length for each concentric fringe, the last one being the longest, reaching half the length of the shell.

Horizon and locality. Upper Utica shale at Holland Patent, N. Y.

Remarks. This species differs from Schizambon canadensis (Ami) not only in size but also in outline, that species being more elongate and having an acute posterior outline. It is of course to be conceded, that the Gloucester shale species of Canada in an early growth stage, corresponding in size to S. minutus probably had a somewhat similar outline, (although hardly as broadly ovate), but no specimens of the size of S. canadensis
about 15 times as large as \textit{S. minutus}, have been found so far in our Utica shale.

The specimen from the Canajoharie shale at Albany, identified by the writer with \textit{S. canadensis} (1901, p. 529) belongs to a new species (see \textit{S. albaniensis}, 1919, p. 105).

Family \textbf{Discinidae} Gray  
Genus \textbf{Orbicuoloidea} d'Orbigny  
\textit{Orbicuoloidea tenuistriata} Ulrich  

Originally described by Ulrich (1878, p. 96) as \textit{Discina tenuistriata}.

The species is known from the Economy member of the Eden at Covington, Ky. A pedicle valve was found by the writer (Ruedemann, 1912, p. 91) directly below the Oneida conglomerate in the Frankfort shale of the Frankfort gulf; a brachial valve was observed in the collection of the United States National Museum from the Frankfort shale at Six Mile creek near Rome; another from the Frankfort "near Rome" in association with \textit{Elperadiata}.

Family \textbf{Craniidae} King  
Genus \textbf{Crania} Retzius  
\textit{Crania laelia} (Hall)  

Bassler, (1916, p. 286) records this species as occurring in the Maysville and Richmond at Cincinnati, Ohio and many localities in Ohio, Indiana, Kentucky, Tennessee etc. In New York, we have found this species at station 22a of the Lorraine gulf section, which represents the base of the Pulaski formation; and also very well represented in a collection of Lorraine shale fossils collected by C. Valient, the discoverer of the appendages of Triarthrus near Rome. In the latter collection it is associated, on the same slabs, with \textit{Triarthrus eatoni} and \textit{Arthropora cleavelandi}, indicating its somewhat earlier appearance there than in the west.

The New York specimens attain only one-half the size (2 mm) of the Ohio material and show a remarkable variability in outline, often approaching a quadrangular shape. The valves, all brachial, are for the most part unattached, though frequently still distinctly exhibiting the sculpture-lines of the shell to which they were attached. The youngest specimens observed are smooth. Several casts of interiors of specimens, apparently belonging to this species,
show distinct anterior and posterior pairs of adductor scars, such as are seen in Crania s. str.

Genus Pholidops Hall

Pholidops subtruncata (Hall)

Pholidops subtruncata was first described and figured by Hall as Orbicula? subtruncata (1847, p. 290) and stated to occur “in the central and upper part of the (Hudson River) group, at Lorraine and Turin, and probably at other places.” It again was figured by the same author (1872, pl. 7, fig. 9). There also the closely related P. cincinnatiensis is figured and P. subtruncata is stated to be distinguished from all the others by its wide and subtruncate posterior border; and the original is said to have came from Lorraine, Jefferson county, N. Y. A further, improved figure was furnished by Hall and Clarke (1892, pt 1, pl. 4 fig. 19).

Foerste (1916, p. 256) has later recorded the occurrence of the species with a very considerable vertical range at many localities in the province of Quebec, as well as in Ontario east; adding, however, that “the subtruncate anterior margin appears to be an individual characteristic, rather than a prevailing one in the great majority of specimens to be referred to this species.”

We have found Pholidops subtruncata to appear rather abruptly and well characterized in station 22 of the Lorraine section and thence persist to the top; and to be likewise a common fossil in the upper part of the Whetstone gulf section (stations 12 and 14). It is very common in the Pulaski section and Foerste has found it still in the uppermost Lorraine beds at Salmon river falls (1916, p. 7).

It is thus a characteristic fossil of the Pulaski shale from its base to the top in New York, and occurs also in Quebec and Ontario east, is hence a characteristic form of the northeastern (Lorraine) embayment of the Maysville sea, while its place farther southwest in the Ohio basin is held by P. cincinnatiensis continuing into Maysville time from Eden time. It is thus quite probable that P. subtruncata is but a local development of the farther spread and longer ranging P. cincinnatiensis and this would account for the fact that Foerste found its main character not to be a steady one; although our New York material would not give such an impression.

1According to Doctor Ulrich (personal information) P. subtruncata occurs also in the Maysville of the Ohio basin.
Pholidops cincinnatiensis Hall

This species which occurs in the Eden and Maysville (Fairview) of Cincinnati and vicinity was originally described and figured by Hall (1872) and again figured by Hall and Clarke (1892, pl. 41, fig. 18). It was found in this State to occur quite regularly in the lower Lorraine (Whetstone Gulf) shales, in the Lorraine, Whetstone gulf and Mill creek sections. In the Lorraine section it was observed only in zone 3, corresponding to the Southgate; in the Whetstone gulf section in zone 1 (Economy); in the Mill creek section in zones 1 and 2 (Economy and Southgate). In the Pulaski formation it is replaced by P. subtruncata and would thus seem to have a shorter range in New York than farther west, where P. subtruncata is not found.

Order Protremata
Family Orthidae Woodward
Genus Dalmanella Hall and Clarke
Dalmanella testudinaria (Dalman)

Dalmanella testudinaria is one of those vigorous persistent species that owing to their adaptability have been able to spread over an immense area (Europe and America) and maintain themselves through a long interval of time (Chazy to Richmond according to Schuchert, 1915, p. 204). It belongs to the group of persistent forms, that the writer (1918, p. 130) has termed "persistent radicles," that is, the original stock continues with apparently undiminished vigor, through a long time, while at the same time continuously geographically and chronologically much more restricted side branches are given off. Such are represented by Dalmanella emacerata, falmountensis fultonenensis, meeki, multisecta, etc., all species (or varieties ?) separated from D. testudinaria in the Cincinnati region and some of which apparently have reached our Lorraine sea. Nevertheless there remain plenty of specimens in all horizons of our Cincinnatian that, so far, can not be split from the original D. testudinaria. This is especially the case with the numberless specimens that fill the impure limestones of the upper Lorraine (Pulaski) formation. It is probable that more refined study than ours will also here in the future be able to distinguish mutations characteristic of different horizons.
The exterior and interior characters of typical specimens of *D. testudinaria*, both from the Trenton and Cincinnatian groups have been fully illustrated by Hall and Clarke (1892, pl. VB, figs. 32–39) and need no further illustration here. We insert, however, drawings of two highly abnormal specimens, from the impure Pulaski limestone, which apparently represent a condition not uncommon in this horizon. In the smaller of these specimens the valve appears trilobed by extremely high ridges, radiating from, but not directly beginning at the raised anterior margin of the muscle-scars. In the larger specimen not only one but three pairs of such sharply projecting ridges are seen, dividing again the shell into lobes. They represent an abnormal diseased condition in my view, which is corroborated by Doctor Clarke; probably consisting in an abnormal calcification of the vascular markings, and injuries to the shell secreting margin of the mantle, which, by interruption of the shell growth, led to the deep sinuses now seen.

In the upper Utica shale so unfavorable to Brachiopod life, dwarfed specimens of a Dalmanella are seen, which may represent but a stunted mutation of the *Dalmanella testudinaria* group.

**Dalmanella multisecta** (Meek)

Plate 12, figures 1–3

*Dalmanella multisecta* (Meek) is one of the close allies of *D. testudinaria* that occur in the Cincinnatian beds and were first distinguished in the Cincinnati region. It was first described and figured by Meek in 1873, (p. 112, pl. 8, fig. 3) as *Orthis emacerata* var. *multisecta*, after it had been mentioned 2 years before as *Orthis multisecta* by James. Hall and Clarke (1892, p. 207) mention it as closely related to *D. testudinaria* and Cumings (1908, p. 901) considers it but a variety of that species and states that it is a smaller form than any other representative of the genus in the Cincinnati region and that its nearly circular outline is also a feature that marks it off from the associated *D. emacerata*. He calls it the characteristic brachiopod of the Eden shale of Ohio, Indiana and Kentucky, its specimens completely filling the rock in many of the layers of the

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1 The smaller form figured there also as *D. testudinaria* (figs. 27–31) was in the same year separated by Sardeson as *D. rogata* from *D. testudinaria* and represents an earlier mutation.

2 These specimens have meanwhile been figured by Doctor Clarke in Organic Dependence and Disease. New York State Museum Bulletin 221–22, 1921, p. 105, fig. 105.
middle and upper Eden. Bassler has found it equally abundant in
the Eden of Virginia (1909, pl. 14) and the writer recorded its pre-

cence in the Indian Ladder beds (1912, p. 51).

We have here referred to *D. multisecta* such Dalmanellas

that are distinguished from *D. testudinaria* by their rela-
tively small size, subcircular shape, flatter sinus and mesial ridge
and finer striae (amounting to 70 to 80 on a valve).

Forms that exhibit, however, all the diagnostic characters of the

species are found in the Lorraine section (stations 11 and 17),
Whetstone gulf section (stations 7, 9, 13 and 14); Mill creek sec-
tion (station 15) and Wood creek section (station 12) and are seen
also in the State Museum collection of Whetstone gulf fossils from
the neighborhood of Rome. In station 9 the specimens cover one

surface entirely to the practical exclusion of other fossils. The

species seems thus to range throughout the Whetstone gulf forma-
tion, but is especially common in zone 2 (Southgate division).
It was also recognized among the fossils from the Indian Ladder beds
by Doctor Ulrich (Ruedemann, 1912, p. 51).

Some of these occurrences clearly represent mutations, charac-
teristic of certain horizons. Thus the form, common at station 14
of the Whetstone gulf section, reproduced here in plate 12, fig-

ure 3, is larger than the typical *multisecta*, namely, 16.5

mm wide and 12.5 mm long, while its striae number 10 in 5 mm
and are hence of the size of the typical specimens. As Foerste
has pointed out (1909, p. 217) there are two extremes figured in
volume I of the Ohio Palaeontology, plate 8, namely, the type
specimens, illustrated by figures 3a to 3d, with finer striae, and
more circular outline, and a more even convexity of the pedicle
valve; and another extreme, illustrated by figures 1a to 1c with

somewhat coarser striations, more triangular outline, and a more
angular convexity of the pedicle valve. The specimens here dis-

cussed belong to the first group. According to Foerste (letter
May 14, 1918) they appear to be most nearly related to those rep-

resentatives of the *Dalmanella multisecta* group

which occur in the lower Maysville.

**Dalmanella emacerata** (Hall)

*Dalmanella emacerata* was described by Hall (1860, p. 121) as *Orthis emacerata* and as occurring in the

Hudson River group near Cincinnati, Ohio, and in Iowa and Wis-

consin.
The original figures were furnished in the Fifteenth Report of the New York State Museum (1862, pl. 2, figs. 1, 3) and the species has since been repeatedly illustrated (see also Pal. N. Y. v. 8, pt. 1, pl. VC, figs. 1, 2). Foerste having lately (1912, pl. 8, fig. 3A, B) given photographs of Hall's type specimen, adding the information that it probably came from the Southgate member of the Eden.

There appear large, slightly convex Dalmanellas with fine striae at several horizons of the Whetstone gulf, which, however, in no case, exhibit the typical proportionally longer hinge line.

**Dalmanella fultonensis** Foerste mut. **lorrainensis** nov.

*Plate 12, figure 7*

Station 17, in the upper third of zone 2 (Southgate division) of the Lorraine gulf section, contains a layer densely covered with a Dalmanella that to us seemed to lie somewhere between *D. multisecta* and *D. emacerata*. Doctor Foerste, to whom we sent a slab with specimens has kindly made the following annotation: "This series shows some resemblance to *D. fultonensis* in the more strongly rounded postero-lateral angles of the shell, and in the coarser radiating striae"; adding, however, in the same letter: "Personally, I do not recognize actual identity between your Dalmanellas and those of the Ohio valley, I merely regard them as near *D. fultonensis*."

*D. fultonensis* which by Foerste was first considered as the typical *D. emacerata* (Foerste, 1909, p. 322) has now been recognized by this authority (1914, p. 129) to differ from the type specimens of *D. emacerata* Hall in the American Museum in being more coarsely striated, having only about 10 striae in a width of 5 mm as against 16 to 17 in the same space in *emacerata* and having more strongly rounded postero-lateral angles. *D. fultonensis* occurs in the Fulton bed, *D. emacerata* in the Southgate division. It is therefore interesting to note the reappearance of this type of Dalmanellas again in New York in zone 2, corresponding to the Southgate division of Ohio, but Doctor Foerste informs me that forms like this reappear again in the Corryville member of the upper Maysville.

The mutation here distinguished has the general outline of *D. fultonensis* but is one-fifth smaller in its largest specimens (16 mm wide) and the striae number 11 to 12 in 5 mm, are hence slightly more numerous than in the Fulton form. The postero-
lateral angles are fully as much rounded as in *D. fultonensis*; the pedicle valve appears to be more evenly convex and the sinus of the brachial valve more distinctly continued to the anterior margin.

**Dalmanella fultonensis** Foerste mut. *rotunda* nov.

Plate 12, figures 4-6

A larger, but otherwise very similar form is found at station 12 of the Whetstone gulf section (near top of zone 2, corresponding to the Southgate division). The specimen here figured is 21.5 mm long and 15 mm wide; the striae number 12 in 5 mm. Its postero-lateral angles are still more rounded than in any of the before-mentioned types, giving the entire shell a characteristic round aspect. We will distinguish this form as *D. fultonensis* mut. *rotunda*.

**Genus Hebertella** Hall and Clarke

**Hebertella occidentalis** (Hall)

Plate 13, figures 1 and 2

The drift material of the calcareous sandstone from the Pulaski formation has afforded several large representatives of this species, collected in the neighborhood of Trenton Falls (Rust collection, United States Nat. Mus. no. 23638).

*H. occidentalis* has been fully described and figured by Hall (1847), from western material and the species reviewed by Foerste (1910, p. 53). It is a well-known fossil of the Maysville and Richmond in Ohio, Indiana and Kentucky. According to Foerste the species is fairly common in the Richmond, but especially common in the Liberty bed and the upper part of the Waynesville. Foerste has lately (1916, p. 84, p. 5 etc.) also shown the occurrence of this species in one or two Maysville localities in Ontario and numerous Richmond localities in Quebec and Ontario. The occurrence in the Pulaski of New York corresponds to its range into the lower Maysville (Fairmount) of the Ohio basin.

**Genus Platystrophia** King

**Platystrophia uniplicata** McEwan var. *uticana* nov.

Text figure 75

We have seen but two specimens of Platystrophia in the Utica shale collection. One of them came from the upper Utica shale at Holland Patent, N. Y., and is now in the United States National Museum.
It is most closely allied to *P. uniplicata*, described by McEwan (1919, p. 405) from the Trenton limestone (undifferentiated lower Trenton in table) "near Lake Champlain, New York." Like that singular form it has but one distinct plication in the sinus of the pedicle valve. This is weakly developed, judging from the figure of *uniplicata*, much less so than in the typical species. The brachial valve is not seen in our specimen. The specimen differs also from the type in being widest at the cardinal line (about 7 mm) and having but six plications on the lateral slopes. These lateral plications are rounded and separated by intervals, fully as wide as the plications. In general outline the specimen is, when compared with the type, relatively longer (length 4 mm).

Under the lens one is able to discern faint traces of another plication on either side of the median plication, a fact that may place the specimen also into certain relationship to *P. trentonensis* McEwan. The specimen has, like most brachiopods in the Utica shale, the appearance not of a young, but rather of a dwarfed form.

Genus **Glyptorthis** Foerste

**Glyptorthis crispata** (Emmons)

Plate 12, figures 8-12

*Orthis crispata* was figured, but not described by Emmons in the final Report on the Geology of New York (1843, p. 404) as a brachiopod that is associated with *Orthis testudinaria* at Lorraine. Although the name was listed and Emmons's figure copied repeatedly, it remained a *nomen nudum* until Foerste rediscovered the form at Lorraine and described it (1914, p. 258), furnishing at the same time the photograph of a specimen.
Doctor Foerste's types were obtained northeast of the bridge in Lorraine and at a locality half-way between Lorraine and Worthville.

**Glyptorthis crispat**a has thus far been found only in the Lorraine section, where we have collected it in zones 2 and 3 of the Whetstone gulf formation and zone 5 of the Pulaski formation. It thus ranges from beds of middle Eden age to such of early Maysville age.

Doctor Foerste has erected the genus Glyptorthis for such species that like the one before us combine the shell form of Hebertella with the presence of concentric lamellose lines of growth. This interesting group which is typically represented by *Hebertella insculpta* from the Maysville division of the Cincinnatian, begins early in the Chazy of Canada with *Hebertella borealis* and *bellarugosa*. With *G. insculpta* the genus reaches the Richmond group.

The first appearance of Glyptorthis in the Chazy sea in two species, one of which spreads afterward west, and again that of *G. crispat* in the Eden sea, but only in its eastern part, is fair evidence of the development of this small group of orthids in the Atlantic basin, whence it repeatedly reached the American epicontinental seas.

**Orthis centrilineata** (Hall)

Under this name Hall (1847, p. 289) has described a small brachiopod from the upper Lorraine (Pulaski) at Lorraine and Turin. Hall and Clarke have not mentioned this fossil again in their monograph of the Paleozoic Brachiopoda (1892), and Foerste (1914, p. 260) expresses the opinion that "it is nothing but a small form of the ordinary Dalmanella, so common at Lorraine, Pulaski, and elsewhere in the New York Lorraine," while Bassler (1915, p. 376) recognizes it as a good species as *Dalmanella centrilineata*.

We have failed to find the type in the collections of either the American Museum of Natural History or the State Museum, nor observed a variety of *Dalmanella testudinaria* that would be marked by "the depressed line extending from the center towards the base of the shell," and which gave the form its name. Hall states that the species "is readily distinguished from *O. testudinaria* with which it is associated, by the slightly elevated convex valve, and the stronger radiating striae, which show no evidence of concentric striae."
Family Strophomenidae  King  
Genus Plectambonites  Pander  

Plectambonites sericeus (Sowerby)  
Plate 12, figure 18  

This widely spread species which is extremely common in beds of Mohawkian and Cincinnatian age in both Europe and America, has not yet been successfully subdivided into the varieties that are supposed to have developed in different regions and horizons, the type having been evidently so well adapted to a variety of conditions that it was able to maintain itself but little changed for a long time. It is also one of the commonest fossils of the Lorraine beds from the first to the last zone, sometimes crowding out all other fossils. The species has been fully figured by Hall and Clarke (1892, pl. XV) and elaborately described by Cumings (1908, p. 923).

Plectambonites centricarinatus Ruedemann  
Ruedemann, (1912, p. 92, pl. 4, fig. 7) describes this as follows:  
The Indian Ladder beds have afforded a rather small type of Plectambonites that is distinguished from the other members of the genus by several peculiar features. The most important of these are the presence of a fold on the pedicle and of a mesial sinus on the brachial valve, the sinus in turn bearing a sharp mesial rib; another is the prominent cardinal wrinkles. It has the mesial sinus and fold in common with a variety of P. sericeus from Snake Hill. The small Indian Ladder type is no longer referable to P. sericeus as a variety, its general form being relatively longer and the valves flatter. This species, in common with P. sericeus var. asper James (rectius P. rugosus Meek) from the Rysedorph hill conglomerate has the cardinal folds, the tendency to less unequal radiating lines than in the typical P. sericeus and also the acute cardinal angles.

Plectambonites plicatellus (Ulrich)  
Originally described and figured as Leptaena plicatella by Ulrich (1879, p. 15).  
This Fulton species was recognized by Doctor Ulrich among the fossils from the Indian Ladder beds at the Indian Ladder near Albany.

Plectambonites rugosus (Meek)  
Plate 12, figures 19-21  
Plectambonites rugosus though first proposed as a nomen nudum by James (Leptaena rugosa), is credited to
Meek, who first (1873, p. 72) figured and characterized the form as a variety of *P. sericeus*, seeing its diagnostic features in the "somewhat larger and proportionally wider shell, with a more straightened anterior margin, and the area of its dorsal valve more inclined forward," as well as in its often having "rather distinct oblique wrinkles along the hinge margin on each side." It seems that this form failed to be recognized as a distinct type, for neither Hall and Clarke (1892) nor Cummings (1908, p. 922) mention it, Cummings stating that *P. plicatellus* is the only other species, besides *P. sericeus*, in the Cincinnati group.

An elaborate account of the history and characters of this type, based on extensive collections has been given later by Foerste (1912, p. 123 ff.). We learn from this that the types of *P. rugosus* were found about 150 feet above low-water mark of the Ohio river, at Cincinnati, Ohio, and thus belong to the Southgate division of the Eden; further that the name *rugosa* (changed by James to *aspera*) was given not on account of the oblique wrinkles along the hinge line but on account of the roughened surface of the general exterior surface of the valves, which is due to numerous very thin overlapping films of shell material. Shells with this structure have furthermore, according to Foerste, a considerable vertical range, though most abundant in the Eden. The oblique wrinkles along the hinge line, Doctor Foerste finds to be not constant at any horizon, and not to characterize any species, as Meek thought. He adds the interesting information that these wrinkles are not an exterior feature, but dependent upon the laws of refraction of light, and connected "with the undulating surface of deposition of the shell material along the linear callosities lining the interior of the valves immediately within the hinge-area."

The relative size of the types of *P. rugosus* is further of importance, Foerste states:

Among the specimens referred to *P. rugosa*, with the oblique wrinkles along the hinge line, many are 12 mm long and 25 mm wide. It is specimens of this large size which occurred 150 feet above the Ohio river at Cincinnati, in the Southgate member of the Eden, and which formed the types of *P. rugosa*. However, specimens of large size occur also at the base of the Eden.

Various attempts to distinguish the specimens found in the Richmond and Eden have not proved very successful, according to

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1 Also the writer has on account of these wrinkles, referred a Plectambonites from the Rysedorph Hill conglomerate to the var. *aspera* James (1901, p. 18), stating at the same time that that feature also appears in the Trenton limestone and Utica (Canajoharie) shale, and therefore does not seem to characterize a different species.
Foerste; although he observed differences in the width of the delthyrium and the anterior outline of the adductor scars, which tends to be more quadratic in the earlier form; differences which however he thinks to be of local use only and denoting but variations of lower rank. He states:

The difference in outline from transversely elongate quadrangular to semielliptical frequently is shown with all intermediate stages on the same slab. All of the shells belonging to the *Plectambonites rugosa* group increase more in width than in length, when attaining a large size. The resultant outline is a matter of luxuriant environment rather than of specific change, and is shown more conspicuously by the larger specimens than by the smaller specimens.

In spite of these negative results, Foerste in recognition of the fact that "if such species as *Plectambonites sericeus* are to be of any value for the closer correlation of the smaller divisions of Ordovician formations, the attempt must be made to discriminate between the smaller variations," distinguishes a *Plectambonites rugosa-clarksvillensis* and emphasizes the value of the slight differences for the stratigraphical paleontologist.

We had our first instruction in the value of *P. rugosa* as a horizon marker when on our joint trip through the Lorraine gulf Doctor Ulrich met the broad Plectambonites in a small limestone band in the first side valley and instantly identified the horizon with the Southgate of Cincinnati, a correlation which has been corroborated by our subsequent work. We have found this broad, transversely elongate and subquadrangular form with apparent wrinkles along the cardinal margins to be a most characteristic and abundant fossil of the stations 15 to 22 of the Lorraine gulf section and stations 10 and 11 of the Whetstone gulf section, there representing the upper part of zone 2 (Southgate) of the Whetstone gulf formation. It is there, for the most part, found in the thin limestone bands that are intercalated in the shale, and contrasts quite distinctly with the small, semicircular forms of Plectambonites that precede it up to station 14 of the Lorraine gulf and station 9 of the Whetstone gulf section. This form we have identified with *P. rugosus* and found to be a dominant fossil of zone 2, although not entirely restricted to it, for it appears again in stations 22a and 27 (zones 5 and 6), hence in beds of Pulaski (Maysville) age.

The cardinal "wrinkles" are seen in both the smaller *sericeus* and the large *rugosus*. In the specimens retaining the calcareous shell in the limestone bands, they are practically invisible, ap-
pearing only as shadows on the surface. On the other hand, in the multitudes of specimens, preserved in the shaly and sandy beds as interior and exterior molds, or both combined, after the entire loss of the shell substance, they are seen as actual wrinkles imposed upon the radiating sculpture lines.

Genus *Rafinesquina* Hall and Clarke

*Rafinesquina alternata* (Emmons)

*R. alternata* occurs in both the Whetstone gulf and Pulaski formations, but is, obviously owing to the shaly facies rather rare in the former while quite common in the calcareous facies of the latter formation. It is there often found together with the nasute form (*R. nasuta*) and persists to the end of the formation as exposed at Bennett’s Bridge and Salmon river falls. In the West and in Canada it enters even into the Richmond.

*Rafinesquina alternata nasuta* (Conrad)

Conrad (1842, p. 260) has described this form as *Strophomena nasuta*.

Hall refused to recognize Conrad’s species, making it a synonym of *R. alternata* and claiming that the latter “presents much diversity of appearance, depending upon the character of the rock” (1847, p. 287), while Cumings (1908, p. 929) recognizes it as a distinct variety of *R. alternata*, found in Indiana in the middle part of the Lorraine, stating that it there is “a somewhat smaller form, characterized especially by the drawing in of the anterior lateral margins so as to give it a somewhat triangular aspect,” as indicated by Conrad. He finds that “the valves are also decidedly more abruptly deflected at the anterior third than is the case in the typical form, thus greatly increasing the convexity of the ventral valve, and to a less degree the concavity of the dorsal valve.”

Foerste (1914, p. 263) states that he found nasute forms of *Rafinesquina* at Pulaski near the upper part of the Trinucleus zone; at Barnes Corners and at Worthville, everywhere in association with forms that indicate the age of the Pulaski formation. He came to the conclusion that it is not likely that these nasute forms constitute a species distinct from *R. alternata* as identified from the same beds, but that their distribution at about the same horizon is possibly of significance for stratigraphic purposes.

Bassler (1915, p. 1088) who recognizes the species as valid, cites it as a Pulaski form in New York and a Maysville form in the Cin-
cinnati region. Whatever the taxonomic position of these nasute forms may be, they prove to be good guide fossils of the Pulaski beds in this State, appearing in the Lorraine gorge in station 22a, or at the base of zone 5 of the Pulaski formation and continuing thence to zone 7, or probably to the end of the section; and occurring also in the upper beds of the other sections.

In the Pulaski section, Rafinesquinas, mostly of the nasute type, are in one sandstone bed swept into compact heaps several feet in diameter by current action.

*Rafinesquina alternata centristriata* mut. nov.

Plate 12, figures 13 and 14

Conrad, in describing *Rafinesquina nasuta*, states that this species resembles *R. alternata* and *R. deltoidea* in having one or two of the central lines larger than the rest, but, as a matter of fact, the typical expressions of *R. alternata* and *R. deltoidea* lack this strong central line, while it is a very constant feature in *R. nasuta*.

Hall (1847, p. 105, 286) on the other hand, in endeavoring to prove *R. nasuta* but a synonym of *R. alternata*, asserts that this line has been considered as a character that is reliable for distinguishing *R. nasuta* from *alternata*, and *deltoidea*, but that it also occurs in the normal *alternata*, and he figures a specimen (op. cit. pl. 31A, fig. 1d) from the Trenton limestone to prove his assertion; and indeed Foerste (1910, p. 44) cites the prominence of the median striation as the most characteristic feature of a Trenton (Cynthiana) form, *R. declivis*, from Kentucky.

If, under these circumstances, we here distinguish a mutation of *R. alternata* on account of the stronger development of the central line, it is because this mutation appears at a distinct horizon and is thus of stratigraphic importance. It is the same with *R. nasuta*, for, although it is true that nasute forms appear already in the Trenton limestone, the distinctly nasute type described by Conrad, occupies a definite horizon in the Pulaski formation. The centristriate mutation of *R. alternata* in the Lorraine beds is a distinct forerunner of the nasute development. *R. alternata centristriata* is common at stations 6, 7 and 8 of the Wood creek section, at stations 8 and 9 of the Whetstone gulf section and at station 6 in the Lorraine gulf section. It thus begins in the Economy stage of the Whetstone gulf
formation and continues into the Southgate division, at least in the Wood creek section, or in the southernmost exposure of the formation in New York.

Hall has figured (1847, pl. 79, 2f, 2f*, 2h, 2i) specimens from the Lorraine beds of New York, that show the character of this mutation. The specimens from the Whetstone gulf formation possess in their smaller size and slightly greater convexity of the pedicle valve features that suggest the later *nasuta*.

A larger centristriate form with flat shell (plate 12, figure 13) is quite common in a bed of Pulaski shale at the railroad bridge at Pulaski.

**Rafinesquina alternata alternistriata** (Hall)

Plate 13, figure 3

*Rafinesquina alternata alternistriata* is a variety of the more common *R. alternata* that is found in the Maysville of Ohio, Indiana and Kentucky (Bassler, 1915, p. 1085). It has been fully described and figured by Hall in Palaeontology of New York, volume 1, p. 109, pl. 31B, fig. 1 as *Lephtaena alternistriata*, as a western form. Its principal differential characters are seen in the relatively greater width of the mostly thinner shell and the alternating arrangement of the coarser and finer striae on the pedicle valve in contrast to the bundled arrangement in *alternata*. On the brachial valve the striae are uniform.

Specimens that exhibit the characteristics of this variety are found in the drift material of the ferruginous arenaceous limestone of the upper Lorraine.

**Rafinesquina ulrichi** (James)

Plate 12, figure 15

This small brachiopod, originally described, but not figured by James as *Strophomena? ulrichi* was later figured by Hall and Clarke (1892, pl. XV.1, figs. 37, 38), who also pointed to the preservation of the primitive condition of the pedicle passage as a tube or sheath in the mature condition of this species.

*R. ulrichi* already has been recorded from this State in the fauna of the Indian Ladder beds (Ruedemann, 1912, p. 51; also erroneously there from the Snake Hill beds). Its type locality is the neighborhood of Cincinnati, where it is found in the Economy horizon of the Eden.
In the lowest beds of the Whetstone gulf formation, corresponding to the Economy horizon, there occur small Rafinesquinas in large numbers, that appear to have reached mature condition; although not wider than 4 mm, and that we have referred to James's species. They give the impression of specimens of *R. alternata* that were retarded in their development in the muddy facies and thus retained their primitive character of the pedicle passage to a stunted maturity; a condition to which most brachiopods of this horizon seem to be subjected, and which also prevailed in the Indian Ladder embayment.

**Rafinesquina mucronata** Foerste

Plate 12, figures 16 and 17

For *original description* see Foerste (1914, p. 265).

The original specimens came from the Nicolet river in Quebec. Doctor Foerste has further recorded this species from the Pulaski beds at Salmon river falls and Pulaski (Foerste 1916, p. 7, 9).

Although this well-marked species has not been recognized until this late date, it is one of the common and characteristic forms of the uppermost Lorraine beds. In the Lorraine section we have found it to fill certain beds in zone 7, of which it is an index fossil. In other beds of this zone it is associated with *Zygospira (?) erratic*. Glacial boulders of Lorraine rock, filled with these two species, are quite common in the middle part of the State, indicating that the extremely hard, and resistant calcareous sandstone of this zone, has furnished a notable portion of the drift and was exposed over a considerable area, although now found only in a few ravines. In the Nicolet river section in Quebec, *Rafinesquina mucronata* is found in an association corresponding to that of our zone 5, and there is little doubt that this small Rafinesquina is a form peculiar to the northeastern arm of the Lorraine sea; although it may be a vicarious form of *Rafinesquina squamula* James, an approximately contemporaneous (Fairmount of the Maysville) form of the Ohio basin.

**Genus Strophomena** Blainville

**Strophomena cf. planumbona** (Hall)

Plate 12, figure 21

While the genus Strophomena is well represented in the Trenton and a whole series (about nineteen) of forms are known from the
Richmond, and also the western Eden and Maysville contain their species, the Lorraine is strangely barren of these ubiquitous brachiopods. Doctor Foerste (1916, p. 25, 43) has observed specimens of *S. planumbona* in beds of Lorraine age in Quebec and in letters to the writer has pointed out the possible occurrence of this species in our Lorraine.

No traces, however, of a Strophomena have been found, with the exception of the fragmentary specimen here figured. This entirely flat, extremely finely striated (15–20 in 5 mm) shell-fragment has all the characters of the flat posterior portion of a pedicle valve of the *Strophomena planumbona-subtenta* group, traces of the sharply bent part being shown along the edge. As both Cumings (1918, p. 941) and Foerste (1912, p. 85) have pointed out, there is no reliable difference between the two supposed species *planumbona* and *subtenta*. The fine subequal striae of our specimen, a feature that has been attributed to *S. subtenta*, are therefore of little or no diagnostic value.

Both of these species occur in the Richmond, but as Foerste's observations in Quebec and this occurrence at Pulaski indicate, may begin already in the Maysville-Lorraine time of the Cincinnatian.

Genus *Leptaena* Dalman

**Leptaena richmondensis** Foerste

Plate 13, figures 4 and 5

The glacial drift has furnished, in the neighborhood of Trenton Falls, N. Y. (Rust collection, United States National Museum, no. 23636), in the characteristically rusty-brown weathering calcareous sandstone of the Pulaski formation several specimens of a Leptaena, that indicate the presence of a form similar or identical with *L. richmondensis* Foerste.

Foerste (1909, p. 211) distinguishes *L. richmondensis* which as *L. tenuistriata* Hall (non Sowerby) is figured in Paleontology of New York, volume 7, page 108, plate 31A and by Hall and Clarke, in Palaeontology of New York, volume 8, part 1, plate 8, from *L. rhomboidalis* (restricted to the Silurian and later periods) by the following characters:

The concentric wrinkles are usually less numerous, less deep, especially toward the beak, and the radiating plications are broader, with narrower intervening grooves. The shell is relatively wider, and in most specimens the top of the pedicle valve is comparatively flat. To this is added in 1910 (p. 45):
The number of radiating striae often is only 9 in a width of 4 mm, the shell is shorter, and is conspicuously elongated along the hinge line, the width frequently equalling twice the length. Moreover, the downward flexure of the geniculate border is less abrupt. The radiating striae are broad, separated by sharp, narrow grooves and resemble pieces of cord in close juxtaposition.

A glance at the figure which is taken from a specimen retaining a combined cast of the exterior and interior of the brachial valve, will show that the Pulaski specimens fall within the bounds of this definition. The number of striae in 4 mm varies between 10 and 13; the number of concentric wrinkles is 5 and the shell is nearly twice as wide as long.

The typical *Leptaena richmondensis* occurs, according to Foerste, only in the upper and middle Richmond beds (lower Waynesville to upper Whitewater) but a form of the lower Richmond (Arnheim) is distinguished as *L. richmondensis precursor* (Foerste, 1909, p. 211). This earlier mutation "varies chiefly in having the top of the pedicle valve more convex. The shell usually is less strongly geniculate anteriorly, and the concentric wrinkles are less conspicuous, often becoming nearly obsolete toward the beak." Our material seems to fail to exhibit the distinguishing characters of this earlier mutation.

Leptaenas of the *rhombidalis* group are also recorded from the Lorraine of Quebec and Ontario east by Foerste (1916, p. 207.)

**Order Telotremata**

**Family Rhynchonellidae** Gray

**Genus Orthorhynchula** Hall and Clarke

*Orthorhynchula linneyi* (James)

Plate 13, figure 6

A solitary example of this species, from the "Utica shale of Oneida county" (Holland Patent), has been found in the Utica collections. It is now in the National Museum and was kindly determined for the author by Doctors Ulrich and Foerste.

While Orthorhynchula in Kentucky and Tennessee ranges from the Trenton to the Maysville, it is very common at two horizons only, the Catheys formation and the top of the Fairview formation and thus serves as an excellent guide fossil for these (Ulrich, 1911, p. 514). In its second invasion, according to the same authority, the species extended northwest along the Alleghany front to central Pennsylvania. Our specimen shows, that between the two inva-
sions, it even reached still farther north, though as a very rare form only. In this case it came from the southern part of the North Atlantic, while in the other invasions it entered with the associated faunas from the Gulf of Mexico.

The species has been fully figured by Hall and Clarke (1892, pl. 56, figs. 10–13, 19) and more recently by Foerste (1910, pl. 3, fig. 10; 1912, pl. 11, fig. 5), who also gives a detailed account of its horizontal and vertical distribution in the Ohio basin.

**Camarotoechia (?) humilis nov.**

Plate 12, figures 22 and 23; plate 13, figures 7–15

The Frankfort shale contains a small brachiopod that in the collections has been identified with *Zygospira modesta*, which in size and character of ribs it strongly resembles. On closer inspection, however, it proves to be a small rhynchonellid, that on account of the solution of the completely flattened shells is not definitely determinable but possesses a septum and distinct teeth and crura and apparently belongs to Camarotoechia.

This species has been cited as Orthis by earlier writers and erroneously referred to *Rhynchotrema inaequivalve* (Castelnau) (Ruedemann, 1912, p. 35, 36), but is distinguished from the Trenton species by its smaller size and much greater number of ribs. It may be recorded here as *Camarotoechia (?) humilis* and described as follows:

Shell small (width of largest specimen 11 mm) broadly subtriangular in outline with rounded anterior margin; about as long as wide; originally depressed convex, with a low fold on the brachial valve and a corresponding sinus on the pedicle valve. Surface of each valve bears from 22 to 28 (mostly 26) prominent primary (undivided) plications, with from 5 to 8 on the fold and 5 in the sinus.

Pedicle valve with prominent umbo and projecting beak; the latter with relatively broad open delthyrium. Hinge-teeth, judging from their molds, prominent. Muscular areas not seen.

Brachial valve less flattened than the pedicle valve and probably originally more convex than the latter. The crural plates not observed; a strongly developed septum extends from the beak to the center of the valve.

**Horizon and locality.** Characteristic of the Frankfort shale, where it is found in the Triarthrus bed at Six Mile creek near Rome, N. Y., and at the Delta dam near Rome; Ilion gulf at Frank-
fort, N. Y., Quaker hill near Northwestern, N. Y., Steele creek at Utica, N. Y. It also appears already in the uppermost Utica beds, as at Holland Patent, N. Y., and is also found in the Deer River shale at Copenhagen, N. Y.

In general habitus this species is quite similar to the form figured by Foerste (1910, pl. 3, fig. 20) as Camarotoechia (?) from a well in the Fulton or lower Eden, 1 mile south of Lower Blue Lick Springs, Kentucky. It is distinguished from the otherwise similar *Oxoplecia calhouni* Wilson (A. E. Wilson, 1913) of the Collingwood shale, by its subcircular outline and smaller size, and from *Zygospira modesta* by the greater number of ribs (22 to 28 against 18.)

**Family Atrypidae Gill**

**Genus Zygospira Hall**

*Zygospira modesta* (Say)

Plate 13, figure 16

*Zygospira modesta* was, as *Atrypa modesta*, already very correctly described by Hall (1843, p. 141) and carefully figured by Hall and Clarke (1893, pl. 54, figs. 7–10, 12).

Foerste (1910, p. 29) has redescribed the type specimens, now preserved in the American Museum of Natural History in New York City.

Hall's type came from the Cincinnati rocks and specimens similar to the type occur in the Fairmount bed at Cincinnati according to Foerste.

Hall states that the species is quite abundant at numerous western localities, but a rare species in New York, where he has seen it only “from the Utica slate, or upper shaly part of the Trenton limestone.” Walcott (1890, p. 348) was the first to record it from our Lorraine. Cumings (1908, p. 940) found that no other species from the Cincinnati series is as ubiquitous as *Z. modesta*. Bassler (1915, p. 1341) records the species as ranging from the Eden to the Richmond and as occurring in Ohio, Kentucky, Indiana, Tennessee, Virginia, New York, Iowa etc. Foerste (1916, p. 223) has likewise found it to possess a long range and wide distribution in Canada (Quebec, Ontario, east and west). In New York it is seen in the Lorraine, in nearly all stations of the Lorraine gulf, Whetstone gulf, the Mill creek, Moose creek and Wood creek sections and is very common in some layers. It is a common fossil in both the Whetstone
gulf and Pulaski formations, and also occurs in the Frankfort shale and the ferruginous drift material.

Zygospira concentrica Ulrich

Plate 12, figures 24-26

For original description see Ulrich (1879, p. 14.)

The outlines of Zygospira modesta Say, are quite similar to those of this shell; that species has, however, from 16 to 20 strong and angular radiating ridges, and only very rarely has the fine and crowded concentric lines preserved; but in this species there are generally no radiating plications (when any do exist, they are only rudimentary), while the concentric striae are well developed; besides the posterior lateral margins are straighter, and the beak of the ventral valve is more pointed, than in that shell.

Bassler (1915, p. 1340) records this species as found in the Maysville (Fairmount) at Cincinnati, Ohio, and vicinity.

This species, some specimens of which were identified by Doctor Ulrich, was found to be common in New York at stations 12 and 13 of the Mill creek section and station 15 of the Moose creek section. In the former section it entirely covers one surface.

Zygospira cincinnatiensis Meek

Plate 12, figure 27

Meek (1873, p. 126) has distinguished this species from the more common Z. modesta.

Bassler (1915, p. 1340) records it as a Maysville (Mount Hope and Fairmount) form, occurring in the vicinity of Cincinnati, Vevay, Indiana and north of Mason, Ky.

A Zygospira probably a variety of modesta approaching cincinnatiensis in the strong development of the mesial elevation and the disposition to bifurcate of the lateral and median plications was found in station 9 of the Whetstone gulf formation (zone 1), hence considerably below the horizon of Z. cincinnatiensis in the west. It is, however, pointed out by Foerste, who has fully discussed (1910, p. 30) the characters of this species, that this type originated already in the middle Eden. Likewise, at station 11 of the Lorraine section, which we consider the base of zone 2 (Southgate) a surface abounds with small Zygospiras of the size of Z. modesta but which in the coarseness of the angular plications and their smaller numbers suggest an approach
to Z. cincinnatiensis. The United States National Museum contains large and finely preserved representatives of this species (no. 23, 553) from the Lorraine shale, 1½ miles east of Rome, N. Y.

_Zygospira (?) erratica_ (Hall)

This important guide fossil of the upper Lorraine horizons was first described by Hall (1847, p. 288) as _Orthis ? erratica_ from specimens found in the drift and received its name therefrom. Together with _Rafinesquina mucronata_ it often fills drift blocks of Lorraine rock, found in middle and western New York. It was also known to him to have been found in place near Washingtonville in Oswego county; and later found by Doctor Ulrich and the writer in place at Pulaski. Dr Foerste (1916, p. 7, ff.) has cited it among the species found by him at Lorraine village and eastward of it, the Salmon river falls section and at Pulaski. It is in this paper shown to appear in the Lorraine section, with zone 5, or the beginning of the upper Lorraine (Pulaski formation) and to continue thence through the following zone to the end of the formation. It can be thus considered a good index fossil of the entire Pulaski formation. In zone 7, it becomes, in association with _Rafinesquina mucronata_, the dominant fossil of the fauna, and we have termed that zone after these two brachiopods. Its range in Canada is still larger, according to Foerste (1916, p. 266), who records its occurrence in numerous localities in the province of Quebec and also in Ontario east of Ottawa. It is considered probable by this authority that the species can be subdivided there. Hall and Clarke (1894, p. 158) have already pointed out the fact that _Zygospira (?) erratica_ is so much alike to the var. _anticostiensis_ of _Catazyga headi_ (Hall) in contour and the fine striation of the exterior that if there is a specific difference it is "too slight, with our present knowledge, to indicate either in words or illustration." This would indicate that _Zygospira (?) erratica_ is extremely closely connected by transitional stages with the later _Catazyga headi_, which according to Foerste apparently replaces _C. erratica_ at the end of the Lorraine and the beginning of the Richmond period.

Both the original description of this species (Hall, 1847, p. 288) and the discussion of the generic relations (Hall and Clarke, 1894, p. 158) with full illustrations have appeared in former publications of this survey.
Hall and Clarke consider *Zygospira (?) erratica* as being intermediary in its characters between the typical Zygospira and the representatives of Catazyga and would therefore use the name Orthonomaeæa, proposed before by Hall in a postscript to the Twelfth Report of the New York State Museum for *Orthis? erratica*, to distinguish the finely striated species represented by *Orthis? erratica* and *Catazyga headi anticostiensis*. Foerste cites the species under Catazyga but Bassler (1915, p. 1340) places it doubtfully under Zygospira. The internal apparatus of *Z. (?) erratica* has not yet been developed because it only occurs as casts in sandstone.
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¹ The results of the last two publications could not be incorporated into the present work.
EXPLANATION OF PLATES

Plate 1

[141]
Sphenophycus lobatus nov.

Figure 1 Type specimen. A rhabdosome of Leptograptus annectans is apparently attached to it.
Upper Utica shale (zone of Climacograptus pygmaeus), Marcy creek, Oneida county, N. Y.

Delesserites salicifolia nov.

Figure 2 Holotype.
Upper Utica shale, Holland Patent, N. Y.

Teganium rauffi nov.

See plate 2, figures 3-5; plate 4, figure 4.

Figure 3 Young individual.
Figure 4 Mature specimen, with rounded outline.
Figure 5 The type. Specimen with angular outline.
Canajoharie shale, Dolgeville, N. Y.
The originals of this plate are in the New York State Museum. All figures are in natural size.

[142]
Plate 2

[143]
Foerstella rotunda nov.

Figure 1 Holotype.
Upper Utica shale at Holland Patent, N. Y.
Figure 2 Parietal tissue; x5.

Teganium rauffi nov.

See plate 1, figures 3-5; plate 4, figure 4.

Figure 3 Very young specimen.
Figures 4 and 5 Specimens showing extremes in variation of outline.
Canajoharie shale, Dolgeville, N. Y.
All figures are drawn in natural size. The originals are in the New York State Museum.

[144]
Plate 3

[145]
Teganium subsphaericum Rauff.

Figures 1 and 2 Two specimens showing the large oscula. Natural size. Upper Utica shale, Holland Patent, N. Y.

Foerstella flabellata nov.

Figure 3 Type specimen, showing the diverging paragastric canals. Natural size.
Figure 4 Cotype retaining traces of paragastric canals. Natural size.
Figure 5 One of these enlarged x5.
Figures 6 and 7 Paragastric canals of the type specimen, enlarged x5, showing the lining parallel rhabds.
Figure 8 Portion of the wall with spicules, x5.
Upper Utica shale (zone of Climacograptus pygmaeus), Holland Patent, N. Y.

Sphaerodictya subsphaerica (Walcott).

Figure 9 Specimen showing part of the wall in section with the exhalent canals and in the center the apertures of the canals. Natural size.
Figure 10 A portion of a cast of the surface x3, showing the large oscula of the exhalent canals and the smaller ostia of the inhalent canals.
Upper Utica shale at Marcy, N. Y.
Figure 11 Restoration, showing the surface on the left and the supposed interior structure on the right.
The originals are in the New York State Museum.

[146]
Plate 4

[147]
Cyathodictya reticulata (Walcott)

Figure 1 Basal portion, showing the stout basal rhabds, x5.
Figure 2 Fragments of surface layer with minute dermalia, x5.
Figure 3 Margin of well-preserved specimen, showing projecting club-shaped dermalia, x5.
Upper Utica shale, Holland Patent, N. Y.

Teganium rauffi nov.

See plate 1, figures 3-5, plate 2, figures 3-5.
Figure 4 Mature individual of irregular outline. Natural size.
Canajoharie shale, Dolgeville, N. Y.

Sycodictya rara nov.

Figure 5 Holotype. Natural size.
Upper Utica shale, Holland Patent, N. Y.

Pyritonema capilliforme nov.

Figures 6 and 7 Bundles of rhabds. Natural size.
Upper Utica shale, Holland Patent, N. Y.

Pyritonema rigidum nov.

Figure 8 Bundle of rhabds. Natural size.
Normanskill shale, Mount Moreno near Hudson, N. Y.

Pyritonema sp.

Figure 9 Small bundle of rhabds, x3.
Upper Utica shale, Holland Patent, N. Y.
The originals of the drawings are in the New York State Museum, except that of figure 5, which is in the National Museum.

[148]
Corynoides ultimus nov.
Figure 1 Group of rhabdosomes. Natural size.
Upper Utica shale of Ohisa creek section (station 5).

Callograptus compactus (Walcott)
Figures 2 and 3 Two rhabdosomes, one compressed vertically, the other laterally. Natural size.
Upper Utica shale, South Trenton, N. Y.

Mastigograptus gracillimus (Lesquereux)
Figure 4 Fragment of rhabdosome, natural size.
Frankfort shale at Delta Dam near Rome, N. Y.

Leptograptus flaccidus (Hall)
Figure 5 Group of three rhabdosomes. Natural size.
Upper Utica shale at Holland Patent, N. Y.
The originals of figures 1, 3 and 4 are in the New York State Museum, those of figures 2 and 5 are in the United States National Museum.

[150]
Plate 6

[151]
Leptograptus annectans (Walcott)

Figure 1  The typical form.
Upper Utica shale, Holland Patent, N. Y.

Leptograptus annectans var. resupinus nov.
Figures 2 and 3  Two characteristic rhabdosomes; original of figure 2, the type.
Upper Utica shale, Holland Patent, N. Y.

Leptograptus annectans var. amplectans nov.
Figures 4 and 5  Two imperfect rhabdosomes; original of figure 5, the type.
Upper Utica shale, Holland Patent, N. Y.

Leptograptus annectans var. patens nov.
Figures 6–8  Three rhabdosomes, showing slight differences in the angles of divergence.
Upper Utica shale, Maynard creek near Marcy, N. Y.
All drawings are in natural size; the originals of figures 1, 6, 7 and 8 are in the New York State Museum, those of figures 2, 3, 4 and 5 in the United States National Museum.

[152]
Plate 7

[153]
Diplograptus amplexicaulis (Hall) mut. uticanus nov.
Figure 1 Type. Utica shale, Herkimer, N. Y.

Diplograptus recurrens nov.
Figure 2 Type. Same as text figure 43.
Pulaski shale, Lorraine village.
Figure 3 Cotype. Same as text figure 42.
Pulaski shale, Loose near station 12 of Lorraine section.
Figure 4 Cotype. Same as text figure 46.
Pulaski shale, Station 15 of Wood creek section.

Diplograptus nexus sp.
Figure 5 Type. Same as text figure 41.
Whetstone Gulf formation, station 1 of Wood creek section.

Glossograptus quadrimucronatus (Hall) mut. lorrainensis nov.
Figure 6 Type.
Whetstone Gulf formation, station 7 of Lorraine gulf section.

Glossogr. quadrimucronatus (Hall) mut. inequispinosus nov.
Figures 7-10 Rhabdosomes and a synrhabdosome (figure 9) showing the position and relative size of the longer spines.
Upper Utica shale, South Trenton, Oneida county, N. Y.

Climacograptus lorrainensis nov.
Figures 11 and 13. Two typical specimens; figure 11, the type.
Figure 12 Group of specimens, showing their average size and character.
Originals of figures 11 and 13 are from the Pulaski shale at Lorraine village, that of figure 12 is from station 18 of the Lorraine gulf section.

Climacograptus typicalis (Hall) mut. posterus nov.
Figure 14 Type. Same as text figure 47.
Atwater Creek shale, station of the Whetstone gulf section.
All figures are in natural size. The originals of figures 2-6, 11-14, are in the State Museum, those of figures 1, 7-10, are in the United States National Museum.
Plate 8

[155]
Lonchosaccus uticanus nov.
Figure 1 Holotype.

Polyplectella mira nov.
Figure 2 Holotype. Bundles of basal tufts, enlarged about seven times.
Frankfort shale, Six Mile creek near Rome, N. Y.

Inocaulis arborescens nov.
Figure 3 Holotype. Natural size.
Figure 4 Cotype. Natural size.
Frankfort shale, Six Mile creek near Rome, N. Y.

Stigmatella sp. nov.
Figures 5 and 6 Exterior and interior views of specimen. Natural size.
Whetstone Gulf shale, Station 12-13 of the Lorraine gulf section.

Aspidopora sp. nov.
Figure 7 Large zoarium of an undescribed species, x2.
Pulaski shale, Pulaski, N. Y.
The originals of figures 1, 2, 3 and 4 are in the United States National Museum, the others in the New York State Museum.

[156]
C. E. R. et E. S. photo.
Plate 9

[157]
**Hallopora andrewsi** (Nicholson)

Figure 1 A typical zoarium.
Pulaski shale, Station 22a of the Lorraine gulf section.

**Amplexopora persimilis** Nickels

Figure 2 A fragmentary zoarium.
Whetstone Gulf formation, Station 12–13 of the Lorraine gulf section.

**Hemiphragma bassleri** nov.

Figure 3 The type.
Figure 4 A larger, somewhat flattened specimen. Cotype.
Upper Utica shale, Holland Patent, N. Y.

**Bythopora arctipora** (Nicholson)

Figure 5 Mold, usual mode of occurrence of the form in the New York rocks.
Figure 6 Squeeze of same to show its original form.
Whetstone Gulf formation, Station 9 of the Wood creek section.

**Serpulites crassimarginalis** Rued.

Figure 7 Specimen from Frankfort shale at Holland Patent, N. Y.

**Protoscolex giganteus** nov.

Figure 8 Holotype.
Frankfort shale, Rome, N. Y.

All photographs are made in natural sizes. The originals of all figures are in the New York State Museum, except those of figures 7 and 8 which are in the United States National Museum.

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UTICA AND LORRAINE FOSSILS

Bulletin 262

Plate 9

E. S. et E. P. photo.
Plate 10

[159]
Stigmatella irregularis (Ulrich)
Figures 1 and 2 Two typical zoaria. Whetstone Gulf formation, Station 14 of Whetstone gulf section.

Aspidopora bellula Ulrich and Bassler ms.
Figures 3a and 3b Dorsal and side views of a zoarium. Whetstone Gulf formation, Station 17 of the Lorraine gulf section.

Leptotrypa minima (Ulrich)
Figure 4 Zoarium, encrusting upon Actinoceras crebriseptum (Hall). Drawn from squeeze. Pulaski formation, Pulaski, N. Y.

Atactopora hirsuta (Ulrich)
Figure 5 Zoarium, attached to cephalopod shell. From squeeze. Pulaski formation, Pulaski, N. Y.

Spatiopora lineata Ulrich mut. compacta nov.
Figure 6 Zoarium, on upper side of the conch of a Geisonoceras tenuitextum (Hall). The cell walls are dissolved. From camera drawing. x5. Upper Utica shale, Holland Patent, N. Y.

Arthrariella lorrainensis nov.
Figure 7 Group of specimens. Natural size. Whetstone Gulf formation, Station 9 of the Whetstone gulf section.

Cornulites progressus nov.
Figures 8 and 9 Type and cotype of the species drawn from squeezes. Figure 8, x4, Pulaski formation, station 22 of the Lorraine gulf section. Figure 9, x2, Pulaski formation. Bank of Salmon river, 2 miles below Pulaski, N. Y.
Figures 10 and 11 Specimen retaining the internal mold; figure 10, enlarged x3, figure 11, the upper portion, x5. Pulaski formation, station 22 of the Lorraine gulf section. All the originals are in the New York State Museum.
Plate 11

[161]
Lingula rectilateralis Emmons

Figures 1 and 2 Topotypes of the species, or specimens coming from the original locality, Rodman, near Watertown, N. Y. Natural size, figure 1 from squeeze.

Lingula bisulcata Ulrich

Figure 3 Specimen from the Whetstone Gulf formation near Rome, N. Y. x3.

Figure 4 A specimen referred here with some doubt from the Whetstone Gulf formation (station 13) of Whetstone gulf. x2.

Crania laelia Hall

Figures 5-8 Four young valves, x5, showing the various expressions of the form. From the Whetstone Gulf formation near Rome, N. Y.

Figures 9-11 Larger specimens. x5, from the same horizon and locality.

Figures 12 and 13 Interior molds of two young valves, showing both the anterior and posterior muscle scars. Figure 12, x3, figure 13, x4.

Figure 14 A very young valve, still smooth, x15.

Figures 12-14 from station 22a of the Lorraine gulf section.

Leptobolus insignis Hall. mut. latus nov.

Figure 15 Holotype. x7.

Deer River shale, Allendale bridge at lower end of Lorraine gulf.

Figure 16 Interior cast of pedicle valve, x7, probably also belonging to this species.

Schizambon minutus nov.

Figure 17 Patch of eurypterid skin covered with specimens of Schizambon minutus. Natural size.

Figure 18 Brachial valve showing marginal spines x17.

Figure 19 Interior of brachial valve x17.

Figure 20 Brachial valve, showing beak and some of the earlier spines. x17.

Figure 21 Pedicle valve, interior mold. x17.

Upper Utica shale, Holland Patent, N. Y.

Trematis millepunctata Hall

Figure 22 Large pedicle valve. x2.

Figure 23 Enlargement (x5) of sculpture.

Pulaski shale, Lorraine village, N. Y.

Trematis crassipuncta Ulrich

Figure 24 Typical specimen x2.

Figure 25 Enlargement (x8) of sculpture.

Pulaski shale, station 22a (near Worthville) of Lorraine section in Lorraine gulf.

The originals of figures 1-16 and 22-25 are in the State Museum, those of figures 17-21 in the United States National Museum.
R. R., G. S. B. et E. K. B. del.
Plate 12

[163]
Dalmanella multisecta (Meek)

Figure 1 Pedicle valve. Natural size, from squeeze.
Station 12 of Wood creek section. Wood creek near Lee’s Center near Rome, N. Y.

Figure 2 A large valve, drawn natural size from squeeze.
From station 10 in the Whetstone gulf section.
Figure 3 A larger and coarser variety, x2.
From station 14 of the Whetstone gulf section.

Dalmanella fultonensis Foerste mut. rotunda nov.

Figures 4 and 5 Two large pedicle valves, from the same shale, drawn from squeezes, x2.
Figure 6 Interior of brachial valve, from same shale x2.
Station 12 of the Whetstone gulf section.

Dalmanella fultonensis Foerste mut. lorrainensis nov.

Figure 7 Two valves (pedicle and brachial valve) drawn from squeezes, x3/2.
Station 17 of the Lorraine gulf section.

Glyptorthis crispata (Emmons)

Figures 8 and 9 Interior casts of brachial valves. Natural size.
From station 23 of the Lorraine gulf section.
Figures 10 and 11 Pedicle valve natural size, from squeeze, and enlargement of surface, x5.
From station 20 of the Lorraine gulf section.
Figure 12 Interior of pedicle valve x2, from squeeze.
Station 20 of the Lorraine gulf section.

Rafinesquina alternata (Emmons) mut. centri striata nov.

Figure 13 Large pedicle valve, natural size.
From the Pulaski shale below the railroad bridge at Pulaski, N. Y.
Figure 14 A smaller well-preserved valve drawn from a squeeze.
From station 6 of the Lorraine gulf section.

Rafinesquina ulrichi (James)

Figure 15 Typical individual, x5.
From station 9 of the Wood creek section.

Rafinesquina mucronata Foerste

Figures 16 and 17 Two pedicle valves, showing the usual appearance of the form x2.
From the glacial drift (Pulaski limestone) near Trenton Falls, N. Y.

[164]
Plectambonites sericeus (Sowerby)

Figure 18 Pedicle valve, x2.
From station 6 of the Quaker hill brook section.

Plectambonites rugosus (Meek)

Figure 19 Pedicle valve, natural size.
From station 15 of the Lorraine gulf section.
Figure 20 Interior of brachial valve, natural size.
From station 18 of the Lorraine gulf section.

Strophomena cf. planumbona (Hall)

Figure 21 Fragment of pedicle valve. Natural size.
From the Pulaski beds below the railroad bridge at Pulaski.

Camarotoechia (?) humilis nov.

See plate 13, figures 7-15.

Figure 22 Type specimen, x2.
Figure 23 Brachial valve, drawn from exterior mold x2.
Upper Utica shale, Holland Patent, N. Y.

Zygospira concentrica Ulrich

Figures 24-26 Three valves in natural size, showing typical expressions of the species.
From station 12 of the Mill creek section at Turin, N. Y.

Zygospira cincinnatiensis Meek

See plate 13, figure 17.

Figure 27 A characteristic pedicle valve. Natural size.
From station 9 of the Whetstone gulf section.
All the originals of the figures of this plate are in the New York State Museum.
Hebertella occidentalis (Hall)

Figure 1 Group of two specimens, interior molds of brachial valves. Natural size.

Figure 2 Large specimen. Same. Natural size.
Pulaski drift near Trenton Falls, N. Y.

Rafinesquina alternata alternistriata (Hall)

Figure 3 Group of two valves. Natural size.
Pulaski drift near Trenton Falls, N. Y.

Leptaena richmondensis Foerste

Figures 4 and 5 Mold and squeeze of the interior of a brachial valve. Natural size.
Pulaski drift near Trenton Falls N. Y.

Orthorhynchula linneyi (James)

Figure 6 Single known individual from the Utica shale. Natural size. Utica shale, Oneida county, N. Y.

Camarotoechia (?) humilis nov.
See plate 12, figures 22 and 23.

Figures 7 and 8 Squeeze and mold of a brachial valve, showing the septum, x2. Frankfort shale near Rome, N. Y.

Figures 9 and 10 Squeeze and mold of a small valve, x3.

Figures 11 and 12 Squeeze and molds of a larger valve on the same slab with the originals of figures 9 and 10, x3.

Frankfort shale at Quaker hill near Northwestern, N. Y.

Figures 13, 14 and 15 Two molds and a squeeze of the second mold, showing two pedicle valves with very sharp ribs, x3.

Frankfort shale near Rome, N. Y.

Zygospira modesta Hall.

Figure 16 Brachial valve preserving the shell and showing well the strong central plication in the sinus, x2.

Frankfort shale near Rome, N. Y.

Zygospira cincinnatiensis Meek
See plate 12, figure 27.

Figure 17 Brachial valve.

Frankfort shale, 1½ miles east of Rome, N. Y.

The originals of all the figures except those of figures 11 and 12 are in the National Museum in Washington; the latter are in the New York State Museum.
E. Stein photo.
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New York State Museum
JOHN M. CLARKE, Director

ALBANY MOLDING SANDS
OF THE
HUDSON VALLEY

BY
CHARLES M. NEVIN

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ALBANY MOLDING SANDS OF THE HUDSON VALLEY

BY CHARLES M. NEVIN

For many years the molding sands of the Hudson valley, popularly known as the Albany sands, although often sold under the trade names of Selkirk, Crescent and North river sands, have been recognized as being specially adapted for brass, aluminum and the smaller types of iron castings. In fact, these sands have been shipped to every part of the United States and have established an enviable reputation for long life and satisfactory performance.

In recent years, however, the idea appears to have become prevalent among some foundrymen that the Albany sands are becoming scarce and that the present producers are not furnishing as uniform or as strongly bonded sand as they did formerly.

In order to investigate this problem, a careful survey was made of the sand deposits in the Hudson valley from Glens Falls to Marlboro, the field work being supplemented by a number of laboratory tests on samples obtained from different pits. The work was of a cooperative nature, the field investigation being made under the direction of the New York State Geological Survey, while the laboratory tests carried out with the support of the American Foundrymen’s Association, were made in the sand-testing laboratory at Cornell University.

The underlying purpose then was to make a complete resurvey of the entire Hudson valley district, and if possible, by analyzing the results of the laboratory tests, to suggest how production in the field and use in the foundry could be controlled and improved.

A preliminary report by D. H. Newland on Albany Molding Sand¹ issued some years ago, covered the general field relations

¹ New York State Museum Bulletin 187. 1916.
and the origin, but there has been an increasing demand among the foundrymen and producers for a more complete discussion of the sands of this well-known district. This should include a tabulation of their physical properties, determined in accordance with the standard methods of testing recently recommended by the joint molding sand research committee organized by the American Foundrymen's Association and the engineering division of the National Research Council.

The writer wishes to acknowledge the many courtesies and the help received from sand producers of the Hudson valley, notably Whitehead Brothers Company, George F. Pettinos, Albany Sand and Supply Company, Charles Pettinos and J. W. Paxson Company. Thanks are also due to Professor Ries of Cornell University for many helpful suggestions.

GEOGRAPHIC DISTRIBUTION

Along both sides of the Hudson river for a distance of about 100 miles, there occur scattered deposits of molding sand, associated with the well-known Hudson river brick clays, large deposits of sharp building sand, and live sand dunes. The Albany molding sand district, with Albany as a center, extends approximately from Glens Falls on the north, to Marlboro on the south, and has a variable width as shown in figure 1.

Such trade names as "Selkirk" and "Crescent" are derived from localities of production or shipping centers in this belt. The term, "North River sands," is applied to those obtained in the lower part of the valley and evidently originated from the custom of calling the Hudson river by that name since it flows from the north into New York harbor.

About one hundred separate strippings were being worked during the summer of 1923, the largest operations being in the central region near Albany although the shipping points show a very wide distribution covering practically the entire area.

Figure 1 Map of the Albany district and its relation to the underlying Hudson River shales

Dotted area is largely underlain by the Hudson River Series
Dashed lines mark limit of the molding sand.
VERTICAL DISTRIBUTION

The elevation or topographic distribution of the molding sand is somewhat variable, due largely to its manner of origin, but in general the best molding sand is found on the high terraces bordering the river valley, with an average elevation of between 250 and 300 feet above sea level. In the northern part of the district good molding sand is often found at 380 to 400 feet above sea level, while in the southern district the elevation is much lower, averaging between 100 and 150 feet. The recognition of this topographic arrangement is useful when searching for new deposits.

ASSOCIATED FORMATIONS

Because of the apparently haphazard distribution of the molding sand, a cursory examination in the field would tend to give the impression that no generalizations should be made regarding its association with the different types of clays, sands and underlying bed rock. By referring to figure 1, which shows the approximate extent of the underlying Hudson River shales and slates of Ordovician age, it would seem, however, that the coextensive distribution of these shales and slates with the molding sand is too well marked to be merely accidental. Of course the shales and slates being comparatively soft were early worn down into a broad, open valley which in recent geologic time held large glacial lakes and since the sands and clays were deposited in these lakes, their extent and distribution were thus partially controlled; but, in addition, it is felt that a closer genetic relation exists and that good Albany molding sand will not be found very far outside the area underlain by the Hudson River slates.

As a general rule, clay deposits are found below the several types of sand, showing that the clay is older and that it was formed under somewhat different conditions. Of the upper or younger deposits, which are predominately sandy, the real molding sand constitutes only a very small part and occurs immediately under the surface soil unless covered by recent sand dunes. Figure 2 shows a typically cross-bedded dune sand covering a ten-inch layer of soil, which in turn is underlain directly by the molding sand. The latter with depth usually changes to a sharp gray sand or sometimes to a clay or gravel.

The live dune sands have very much the same appearance as the

1 Ancient Water Levels of the Champlain and Hudson Valleys. New York State Museum Bulletin 84. 1905.
molding sand except that they are still shifting, are usually of a lighter color, show cross-bedding and sand dune outlines, and lack the bonding strength of the true molding sands. A closer examination of the dune sand, however, shows a marked similarity to the molding sand in the size and shape of the sand grains, but differs from the latter in the presence of undecomposed shale particles.
and the absence of coloring due to lack of iron compounds. In many places these active sand dunes form well-marked topographic features, and because of their continual shifting are a constant hindrance in the prospecting and development of the underlying molding sand.

Since the sharp gray sand is usually covered with soil, molding sand or sand dunes, its distribution and extent may be easily overlooked. Consisting of angular particles of metamorphic rocks, essentially slates, phyllites and quartzites, this gray to black sand is in marked contrast to the yellow-brown molding sand, into which it often grades rapidly. Moreover the sharp gritty feel of the gray sand easily distinguishes it from the associated molding sand which has a characteristic smooth, velvety feel. This difference in feel and color is used by all the field foremen in judging how deep to dig their molding sand.

In the Hudson river district the open gray sand shows a very wide distribution and an enormous tonnage, but it has always been considered of no economic value. Physical tests have shown that this gray sand has all the necessary qualities for a good concrete or mortar sand and that it usually does not require washing.

Recently the New York Sand and Facing Company, on one of its molding sand properties near Marlboro, where the molding sand averages about 2 feet in thickness, decided to try barge shipments of the underlying gray sand for building purposes. A drag line and belt conveyer were installed and the gray sand was dug to a depth of more than 50 feet. Since this particular deposit was found to be entirely free from gravel and required no washing, the profits from this previously neglected natural resource soon far surpassed that obtained from the associated molding sand.

Similar conditions exist in many other places in the Albany district and where cheap transportation and loading is available, it would seem that the gray sand could be profitably handled to supply building demands even as far away as New York City.

CHARACTERISTICS OF THE MOLDING SAND DEPOSITS

An outstanding characteristic of the Albany molding sands is that within short distances they show great variations in practically all their physical features. Indeed, there appears to be no uniformity in distribution, topographic form, thickness or physical properties, and since these variations control every phase of the molding sand industry as well as the probable origin of the deposits, a correct appreciation of them is essential.
One striking exception to this lack of uniformity is the fact that the molding sand occurs next to the soil layer. This is universally true over the entire district, and therefore would seem to be related in some way to the origin. It was also noticed that the molding sand occurring in a timbered tract or under heavy vegetation always had a stronger bond than similar sand just a few feet beyond the timber line. In fact vegetation often reflects the presence of sharp, open, unsatisfactory sand underneath by being stunted and full of thistles. From what has been said above, however, it must not be inferred that every good soil is underlain by molding sand, for such is not the case.

The molding sand may be found at almost any elevation between 100 and 400 feet above sea level, although, as already mentioned, the higher lying deposits predominate in the northern part of the district, possibly because the upland terraces bordering the Hudson river also show a relative increase in height to the north. At any rate, the sand is best developed on these stream terrace areas where it has been protected from dissection by streams. Often the molding sand shows a distinct sand dune topography but such deposits are not shifting at present and doubtless have been anchored by the covering of vegetation for many years.

Thus the cutting up by stream erosion, the working over by wind action, the original differences in deposition and the final 10 to 12 inches of soil veneer make the estimates of available tonnage worthless unless they are based on very careful test-pitting. So far as distribution is concerned, as one producer aptly said, the molding sand is where you find it.

THICKNESS OF DEPOSITS

The molding sand varies in thickness from a few inches to 8 or 10 feet, depending on the origin and local conditions. It usually forms a layer of about 18 inches thickness immediately under the soil and follows the topography rather closely, although it is slightly thicker on the flats and thinner on the gentle slopes. Where the slopes become steep, the molding sand layer thins out or disappears. This layer type is so common and widespread that it makes the average thickness of the molding sand for the entire Hudson valley district about 20 inches, thus forming quite a contrast to some of the New Jersey and Virginia deposits which are thick enough to permit the use of steam shovels. One noteworthy feature of this normal type is the absence of distinct stratification or bedding planes.
In rare cases a thickness of 8 feet or more of good molding sand is discovered and in such deposits the stratification planes are usually distinct, the molding sand being sometimes split by thin layers of sharp sand or clay. Examples of this type were noticed near West Albany, Elnora and Ushers, where banks with a face of 8 feet were being operated. Sometimes in these stratified deposits patches of sharp sand or clay become so pronounced that development is stopped or else they are dug around and left behind as islands.
One factor which influences the thickness is the unevenness of the floor on which the sand rests. When this is a sharp gray sand having a grain size similar to the overlying molding sand there is usually no unevenness except as the molding sand layer
rises and falls with the topography. In many cases, however, the molding sand is underlain by gravel, clay or bed rock which often have an eroded, irregular surface, thus making the thickness variable and tending to show that the molding sand has been moved there from its original position.

TEXTURE

Perhaps the texture or fineness has done more than any one thing to make the Albany molding sands famous and yet this grain size, as found in the field, is extremely variable. In an area no larger than 10 acres all the grades from no. 0 (fine) to no. 3 (coarse) are often found and the recognition and separation of these grades is a very difficult matter. The extreme grades, nos. 00 and 4, are not as widespread as those suitable for brass and stove plate castings, but no matter what grade is being dug, sudden changes in texture are the usual thing and seem to follow no set rule.

When the molding sand has the outlines of a sand dune topography the finer grades are sometimes found on the south side of the old dune due to the former prevailing direction of the wind. Often the former trend of the water currents can be approximated over a small area and coarse and fine grades discovered ahead of development, but the controlling conditions are so many and varied that a constant changing of texture is the normal result. Even large boulders are quite frequently found in the fine sand.

BONDING STRENGTH

The bonding strength or cohesiveness also continually changes with the same apparent disregard of law and order. Under heavy vegetation or down the gentle slopes of the hillsides the deposits are usually stronger in bond but exceptions to this are numerous. In fact, the amount of bond changes just about as quickly as the texture and since they together determine the worth of the sand, it is quite evident that the production of good Albany molding sand requires plenty of experience and specialized training.

SHAPE OF GRAIN

Under the microscope, when washed clean, the individual sand grains show a pronounced angular to subangular outline, increasing in angularity with the finer sizes. This lack of rounding has an important influence on the behavior of the molding sand in the foundry as well as being reflected in the physical tests. In addition,
a clue to the possible manner of origin is suggested since water-worn sand grains have a characteristically rounded form in contrast to the subangular grains associated with conditions of glacial erosion and deposition.
COLOR

The typical color of the Albany molding sand is from a dark to a light yellow-brown, which is caused by the different amounts of hydrated iron oxide as well as by varying degrees of oxidation of the iron. This coloring is in the so-called "clay substance" or bond which forms roughly about 15 per cent by weight of the molding sand. Usually some of it is so tightly held or absorbed by the sand grains that repeated washings and even dilute acid treatment fail to give a white sand. Examination under the microscope, however, shows 90 per cent of the washed sand to be composed of clear, white quartz grains with the remaining 10 per cent a scattering of dark ferro-magnesian silicates (such as hornblende and biotite mica), unweathered shale, and feldspar particles. Sand with such a mineral content could be derived from areas of quartzites and other metamorphic rocks such as lie to the north of the Albany district.

ORIGIN

Objection might be made that a detailed study of the origin of the Albany molding sand is a theoretical problem outside the interests of the practical foundryman and producer. Such a consideration is essential, however, for a correct understanding of the many variations and characteristics already described, as well as a guide to future prospecting and development.

These molding sands illustrate unusually well a rather specialized manner of origin and deserve to be established as a type.

When writing about the unconsolidated, surface deposits of our northern states it is usually necessary to consider glacial conditions, and the gravels, sands and clays of the Hudson valley form no exception to this general rule. Although the last advance and retreat of the great Pleistocene ice sheet occurred 20,000 years ago, more or less, and although it did not directly furnish Albany molding sand, it nevertheless is responsible for the present molding sand and brick clay production of this district.

Sweeping down from the north, bearing a tremendous load of ground up rock débris scoured from Canada and the Adirondack mountains, the ice completely overran the Albany district. The fact that the soft shales and slates of the Hudson valley were easily plucked by the moving ice and formed a large percentage of its burden in the molding sand territory, is noteworthy. After the ice had reached the maximum advance and started its irregular retreat, all of the transported boulders, gravel, sand and shale particles were dropped, forming moraines and huge deposits of partially sorted
material, which were continually being changed and more perfectly sorted by waters from the melting glacier.

It is not intended to review here the different stages of the ice retreat with their attending glacial lakes as this has been thoroughly treated in several bulletins of the New York State Geological Survey. The broad, general fact that the retreat of the ice was very irregular and that the normal drainage was impeded by glacial conditions to such an extent that large lakes were formed, should, however, be emphasized. One of these lakes, named Lake Albany, formerly covered the molding sand district of the Hudson valley and in it were laid down the sands and clays that are of present importance. Such lakes as Round lake, Ballston lake and Saratoga lake, which today occur in the midst of these deposits of former Lake Albany, doubtless occupy the sites of stagnant, mantle protected masses of ice which persisted during this deposition of sand and clay.

Lakes act as great settling tanks and the deposits formed in them are more uniform than river laid material. The speed of the tributary streams, shifting lake currents, and the size and shape of the particles of sediment are the controlling factors and the separation of sand and clay is often very complete. Such is the result in the Lake Albany sediments where clays were first brought down by the Mohawk and other rivers and spread out over the lake floor. During the last stages of Lake Albany, sands formed the predominating sediments and as a final consequence the Hudson valley in many places was filled with these deposits to a height of about 400 feet above the present river level. The disappearance of Lake Albany and the reestablishment of the Hudson river drainage, with a consequent cutting through of the lake deposits, were the closing developments of the glacial period.

Since very little vegetation was present to anchor the newly laid deposits the wind must have worked over the sand to a considerable degree. Evidences are seen in old, anchored sand dunes, in the distribution of the sand at almost any level above the surface of the Hudson river, and in the usual absence of well-marked bedding for any distance. Of even more importance is the additional sizing of the sand grains which was an aid to the preliminary water sorting and oftentimes gave a quite different product. J. A. Udden has shown that the wind traveling at 8 miles an hour will

1 New York State Museum Bulletins 84 and 106.
carry sand grains averaging 0.18 millimeters in diameter and Boswell\textsuperscript{1} has noted that wind blown sands in England are composed of 80 per cent of grains between 0.25 and 0.5 millimeters.

Therefore it would seem reasonable to suggest that the unusual

\begin{figure}[h]
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\includegraphics[width=\textwidth]{figure6.jpg}
\caption{Sharp, gray sand above the Hudson Valley clays. Weathering has changed the upper part to a molding sand.}
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\textsuperscript{1} P. G. H. Boswell. Memoir on British Resources of Refractory Sands for Furnace and Foundry Purposes.
grading curves for no. 3 Albany sands shown under the chapter on sieve tests and grading, where a very small amount of silt is present and the 70-mesh sieve retains from 30 to 60 per cent of the sand, are due to selective sorting by the wind.

Sand deposits formed under conditions such as existed in the Hudson river valley might be expected to show a general average fineness with minor variations due to shifting lake currents and sorting winds; to consist of angular to subangular sand grains due to lack of water erosion; to be nonuniform in their distribution; and to contain occasional large erratic boulders because of the droppings from floating icebergs. That this describes the Albany molding sands is quite evident.

Although the glacial forces furnished the material, it required the further influence of natural agencies working through a period of several thousand years, to develop the proper physical conditions necessary to make a good molding sand. In fact, the real worth of any molding sand is very largely determined by its physical rather than chemical properties.

Briefly, the ordinary processes of surface weathering are thought to have changed the easily attacked particles of Hudson River shales into a clayey substance which now forms the bond of the molding sand. Many other nonresistant mineral particles, such as feldspar and pyrite, were also changed but because of the far greater abundance of the shale and slate particles in the unaltered sand, the bond is attributed to them. In other words, the active dune sands and especially the sharp gray sand are potential molding sands but lack the proper physical condition given by thousands of years of weathering. So the association of the sharp gray sand, the active sand dunes and the Hudson River shales and slates of Ordovician age with the Albany molding sand, is really a genetic relationship, and the sharp gray sand may be thought of as the "mother sand."

That these weathering conditions and reactions are not simple is realized. Even where an apparently simple change of the iron in pyrite to a hydrated iron oxide has occurred, the chemical aspect is easier to understand than its final physical character. So in the alteration of the shale and slate particles which are composed of materials released by the previous weathering of rock débris, the reactions are extremely complicated and difficult to estimate.

The unvarying occurrence of the molding sand next to the soil layer and the usual increase of bonding strength where the sand is overlain by timber or heavy vegetation seems to indicate the
importance of the action of plants. Penetration of the roots gives weathering processes a better foothold and the decay of these roots and the overlying vegetation forms humic acids that chemically

attack the surrounding rock particles. Bacteria also help to form humus and other substances which have a flocculating effect on colloidal gel in and immediately below the soil.
Weathering of the sharp gray sand would tend to give colloidal suspensions or sols and when such particles are brought into contact with others bearing an electric charge of opposite sign, such as humus, both are precipitated and under favorable conditions a colloidal gel is formed. Silica, clay and iron when they hydrate, are particularly prone to enter into the colloidal gel state, and many of the properties of molding sand are due to this fact.

The bond appears to possess a honey comb or space lattice arrangement which permits the taking up of many times its weight of water, forming a gelatinous, sticky mass, which coats the quartz grains. Further study and comparison of the bond of molding sands is necessary, and physical rather than chemical relations would seem to offer the best method of attack.

The following chemical analyses of the gray or "mother sand" and also of the molding sand immediately above it, tend to uphold the ideas of origin already advanced. A complete analysis was not made, but by referring to analysis no. 1, which is an average analysis of three Albany molding sands, it will be noticed that the main constituents were determined. In addition the bonding material, amounting to 15 per cent by weight, was separated from the molding sand in the manner outlined under sieve testing, and analyzed.

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No. 1 Average of three complete analyses, Ries and Rosen
No. 2 Albany molding sand
No. 3 Gray sand immediately under no. 2
No. 4 Bond of no. 2
No. 5 After complete washing of no. 2 and short treatment with dilute nitric acid

Comparing now the molding sand no. 2 with the gray sand no. 3, their similarity is apparent and it would seem that the gray sand could furnish everything necessary to make a good molding sand. As is to be expected the molding sand runs a little higher in loss on ignition because of its hydrated bond.

This bond is composed of colloidal particles which in part are held so tightly to the sand grains that they can not be washed clean. Even after fifty washings and a short treatment with dilute nitric acid
acid the sand still had a yellow-brown color and analysis no. 5 seems to show that some of the bond was still present as well as a few particles of unweathered shale and feldspar.

Figure 8 Pitted glaeconite grains—a source of bond for many New Jersey and Virginia molding sands

Analysis no. 4 is the bond which constitutes 15 per cent by weight of the molding sand and carries the greater part of the hydrated clay and iron. In striking contrast, the gray sand when washed lost
only 1 per cent of its weight, thus tending to show that the iron and alumina in this sharp sand are not in the colloidal state where they could be used as bonding material.

Figure 9 Cavities in thick molding sand beds, formerly filled with sharp beach sand. The bedding is also an indication of water origin and contemporaneous deposition.

These analyses seem to demonstrate that the sharp gray sand could furnish the bond of the Albany molding sand by the breaking down of its metamorphic rock particles and that the final physical
state and arrangement of this colloidal bond is the important factor.

If we accept this manner of origin, the twenty-inch layered form of the Albany sand would represent the usual depth of weathering, determined largely by the position of the ground water level. The increase in strength of the sand under heavy vegetation and down the gentle slopes as well as a general following of the topography, are thus easily understood. When the molding sand layer passes into the underlying sharp gray sand without a change in grain size, as it often does, there has been no disturbing or shifting during the weathering. Even the great variation in the amount of the bond is attributable to such a manner of origin, since depositional differences in the composition of the "mother sand" as well as differences in weathering would certainly be reflected in the bonding strength of the molding sand.

A weathering type of origin for the bond is applicable to many deposits of molding sand in districts outside of the Hudson valley. Indeed, it is exceptional for any molding sand deposit not to show a decrease in quality with depth, because of weathering influences. Many of the well-known molding sands of the Atlantic coastal region largely owe their bonding strength to the breaking down of glauconite or "green sand" and the accompanying photographs of partially weathered green sand show how the glauconite weathers to form a coating for the associated quartz grains. These pitted glauconite grains are in distinct contrast to the Hudson river shale particles of the Albany district, and naturally the resulting bond and behaviour of these molding sands is different. In fact, as yet no molding sand has been found that is an exact substitute for the Albany sand simply because its origin has not been duplicated.

The occasional deposits of Albany molding sand extending to a depth of 8 feet or more, often mixed with layers and lenses of sharp beach sand, are believed to have been deposited as a molding sand and hence do not merely represent unusually deep weathering. In fact, such deposits have not been materially affected by weathering since their deposition.

After the reestablishment of the Hudson river drainage a large amount of material that had already been weathered enough to make a molding sand must have been scoured off during heavy floods. The dropping of this molding sand in quiet lagoons would give deposits of the finer grades such as are found at West Albany, Elnora and Ushers, which are very thick. At West Albany it was noticed that the upper 2 feet of the eight-foot face was of a much lighter color due to oxidation although the whole face furnished
good molding sand, thus showing that weathering since deposition had only a minor effect. The association of "islands" of useless sand and the well-marked character of the bedding also helps to separate this type of origin from the usual occurrence.

A fallacious idea exists that the molding sand will renew its bond in 20 or 25 years and several cases are known where producers have taken molding sand from a property that had been stripped 20 years before. Upon investigation it was discovered that the initial stripping had not been complete as in the early days only the best of the sand was taken and thus much fairly good molding sand had been left behind.

In closing these remarks on origin it might be well to emphasize the fact that the making of the bond was a matter of several thousands of years, that it was a very complicated process, and that it is still slowly going on today.

PRODUCTION AND GRADING

Because of the continual variation in thickness, texture and bonding qualities, the production of a high-grade Albany molding sand requires experience and constant supervision. All of the sand is dug by hand, being loaded onto trucks or wagons and then either temporarily placed in large stock piles or unloaded directly into railroad cars and barges. By the time this sand gets to the foundry floor, especially if it has gone through the stock pile stage, the constant rehandling has given a rather uniform product.

At the banks the sod and soil are first carefully removed in strips of about 3 feet in width and thrown into the adjacent dug over strip, from which the molding sand has been removed. If correctly handled, the field can be returned to cultivation after all the molding sand has been taken out.

The foreman by using his fingers and thumb, determines the texture and strength of the sand and endeavors to keep separate banks for each change in these properties. In loading a wagon with one grade of sand the experienced foreman will often dig from three or four banks to secure the desired result in texture and bond. In addition, the depth to which the sand is dug must be watched carefully as the floor is generally irregular and the inclusion of the underlying sharp gray sand always hurts the value of the molding sand.

Such briefly is the method of production and at first it would appear to be very primitive, for in fact it is the same method that
has been used since the deposits were first discovered. Yet it is the only practical way to handle material that is so variable.

Some foundrymen believe that the Albany sand now being produced is not as uniform in grade or as strong in bond as it was formerly. This belief is partly true since only the best of the sand was formerly taken, and yet there is today plenty of Albany sand as good as was ever shipped. The tendency seems to be, however, to keep the production large and therefore as much of the
more open sand as possible is blended with the stronger. If the foundry really requires a strong sand it can readily be obtained if the producer wishes to dig it.

At present no extra charge is made for this specially picked strong sand, and it would seem that the producer is entitled to one as he is thus losing tonnage by leaving the more open sand undug. It also seems strange that the foundrymen should order a weak or open Albany sand, when the blending of some of the partially burnt sand or the addition of a sharp, cheap, local sand of the right texture, to a strong Albany sand would give the desired result more economically.

Quite a few independent producers have sprung up and in many cases they are underselling the older ones. Some of these independents go into districts that have already been stripped of their best sands and take out the remainder, naturally obtaining a poor product. Others purposely take too deep a face, mixing in the sharp gray sand and getting a weak unsatisfactory product, which is sold cheaply. All of these factors taken together have given a basis for the belief that the present Albany sand is not as good as it was formerly.

In regard to the question of standardized grades and a uniform product by control methods in the pit and at the stock piles, the writer was told many times that it is impossible to establish any standard that would have a practical application and yet his informants freely admitted its need.

In the early days the grades were doubtless established by Whitehead Brothers, but with the spread of the industry others entered and today there may be quite an appreciable difference in any one grade as shipped by the different producers. Moreover, the foundrymen themselves are often in error on their grade sizes as for instance when some foundries order a no. 00 grade for bench work. If the producer knows that it will be used for bench work he will ship a no. 1 or 1½ grade and have a satisfied customer. A case comes to mind of a foundry that placed an order for a no. 0 sand and since it was a new customer the producer took special pains to see that a good no. 0 sand was shipped. The shipment was refused and upon investigation it was found that a no. 3 sand was what the foundry needed, which of course was easily supplied. All of this could have been avoided if the sand had been bought on a sample basis, as the producers can match any grade that the foundry is using between no. 00 and no. 3.

At the present price of molding sand it will not be a practical solution even to try to control the digging or the stock pile by any
sieve test. In fact, sieve tests of molding sands are not depend¬
able unless made on a sample that has been washed free of its
bond. The finger and thumb method is the only one that would
seem to serve and the writer thoroughly believes that this method
is excellent if all of the fingers and thumbs are trained on the
same standard grades. Yet these standard grades should be estab¬
lished as to size of grain, permeability and cohesiveness by the
standard tests.

The following method appears to be a practical solution. Using
the standard sizes or grades that are recommended in the chapter
on sieve tests and grades, establish stock bins of these types at one
of the American Foundrymen's Association sand testing stations,
these grades to be determined by the standard tests. This would
mean bins containing strong and weak, open and close representa¬
tives of the six recommended grades. In fact, it would seem that
grades and types so established could be used for molding sands
from any state that fall within these limits. This would do away
with such contradictions as a Kentucky stove plate sand being
called a no. 6 in contrast to the same sand in the Albany district
being graded a no. 1.

Small samples from these bins of type sands could be sent, on
request, to the producers and foundries. With these small samples
the foremen could educate their fingers and thumbs all to the
same feel, and uniformity should be the final result. The writer
has seen so much accurate grading done by experienced men by
merely feeling the grain and judging the strength by a rough break,
that he feels confident that it is not a slip-shod method and that
it is the only practical method for field control. All that is needed
is a uniformity in training.

STANDARD TESTS

While tests of the Albany and other molding sands have appeared
from time to time, a satisfactory comparison of these tests could
not be made as they were not all carried out in the same manner,
but since the American Foundrymen's Association has recommended
several standardized methods for determining the properties of mold¬
ing sands, it is now possible to obtain concordant results.

Incidentally, the development of these tests has also permitted
the examination of untried sands with the expenditure of much
less time and money than was formerly possible. In fact, we
might say that the whole subject of the behavior of molding sands
and the governing factors that make some sands so far superior to
others, could not be intelligently studied until standard testing methods were developed.

Properties Studied

The properties of the molding sands which were studied, and to which reference is made are fineness, permeability, bonding strength and the relation of water to the permeability and bonding strength.

Method of Obtaining Samples

Some sixty samples were collected from the Albany district. Instead of taking these in person at the bank, the writer asked the firms of Whitehead Brothers Company, G. F. Pettinos, C. Pettinos, Albany Sand and Supply Company, and J. W. Paxson Company to supply him with samples of the different grades they produced. Special care was to be taken in the selection of the samples so that they could be considered as representative of the grades recognized by these producers. To all of these firms acknowledgments are due for the willingness with which they have responded.

With regard to the selection of the different grades at the bank, most foundrymen know that it is made by the "feel" method.

SIEVE TESTS AND GRADING

Since the size and shape of the sand grains control to a large degree the physical properties of molding sands as well as the type of work to which they are fitted, it was thought best to consider the fineness test first and if possible to group accurately the sands into standard grades. With such a preliminary grouping the subsequent discussions on permeability and bonding strength should be on a more comparable basis.

The fineness test was carried out as recommended by the sub-committee on standard tests as follows:

Fineness Test\(^1\)

A fifty-gram sample of thoroughly dried molding sand is placed in a one-quart jar, and 475 cubic centimeters of water and 25 cubic centimeters of a standard solution of sodium hydroxide are added and the jar tightly corked. It is then agitated in a shaking machine for 1 hour, allowed to stand 10 minutes and the suspended matter siphoned off. More water is added again and at the end of 5 minutes siphoned off. This process of five-minute standing and siphoning is repeated until the water remains clear at the end of the five-minute

\(^1\) For a complete description see Trans. American Foundrymen's Association, June 1924.
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period.
grain.

By this means the “ clay substance ” is separated from the

The grain remaining is collected, dried thoroughly and weighed.
Then the grain is placed on the first of a series of sieves, United
States Bureau of Standards, and the sieve nest placed in an auto¬
matic shaker, which is run for 15 minutes.

The amount remaining

on each sieve is weighed and expressed in percentage.

The amount

lost from siphoning is called “ clay substance ” and the amount that
passes the 270-mesh sieve is weighed as minus 270.
The following table gives the results of the fineness test on the
sands collected.
Fineness tests
Number

209
221
231
251
253
254
203
206
207
232
238
240
241
244.
249.
255.
258.
3.60.
361.
215.
228.
239.
250.
259.
260.
364369.
21 r .
213.
246.
256.
362 .
365 •
370.
371 •
204.
205 .
208.
212.
214.
216.
245.
248.
261 .
257 •
262.
263 .
363 •
210.
217.
218.
219.
220.
247.
252.

On
6

•30

On
12

.14
.38
.18
.04
.20
.26
.04
.04
•38
.22
.04

.02
.04
. 06
. 16
. 16
.08
. 10

.14

.24
. 12
.04
.14
. 20

. 12
.14
• 30
.46
.76
.78
.38
.64
.24
.60

. 16
.04
.22
.06
.20
.12
.46
•44
.04
.82
. 20

.24
.50
. 22
.18
. 16
• 36
• 90
• 32
• 98
.64
. 22
.82
.14
.96
2.00
1.42
2.24
1.48
2.88
• 74

On
20

On
40

On
70

On
100

On
140

On
200

On
270

Through
!
270

.06
.16
. 10
.06
. 12
. 12
.08
. 10
.18
. 20
.02
. 10
.04
.02
.06
.12
.12
.08
. 22
. 12
.14
. 06
. 16
.08
.10
. 10
. 16
.04
.64
•34
. 10
.14
.18
.02
.02
.20
• 90
• 52
• 36
. 10
•34
1.16
• 70
2.62
.68
.68
.80
. 12
132
3-30
2.30
2.64
2.08
2.94
2.46

.26
.26
. 22
.04
.22
• 32
.20
.42
•30
.12
. 12
• 34
• 32
.02
.02
• 50
.40
•54
.42
.28
• 44
. 16
• 30
. 12
.40
1.22
• 36
1.04
2.18
•SO
1.60
1.64
1.46
1.00
• 72
3-86
.82
2.00
5.70
1-74
2.60
7.06
3.96
10.08
8.74
6.20
8.00
3-88
19.14
18.96
16.50
5.58
23.20
5.50
1.94

1.16
1.78
• 44
•54
.62
.86
1.30
3-50
2.12
1.10
.62
1.02
1.06
2.48
1.92
2.70
3-44
3-70
2.32
2.48
6.50
4-32
4.76
• 50
1.88
10.22
2.36
24.68
11.10
15.04
22.24
17.16
17.00
26.50
19.68
46.44
52.38
29.16
28.90
35.84
44-74
37-28
56.74
22.70
36.24
3<3 • 64
28.44
30.98
41 • 56
32.20
53 16
64.08
42.70
52.8o
63.OO

1.28
2.98
.80
1.60
1.28
2.44
3.16
3 04
4-92
4.78
2.20
4.48
4.16
4.02
3-46
3 08
4-50
1.98
1.36
9.48
15-06
16.90
8.08
6.74
10.24
9.92
11.08
21.94
14.96
25.60
12.24
7.62
15.42
22.98
20.18
18.86
7.64
15.64
15.86
20.50
1730
16.82
11.18
18.32
7.56
18.84
19.50
11.04
5.26
4-34
3-22
5.64
4-30
6.72
4.40

2.26
4-54
2.80
6-34
5.56
5-88
.7-58
3-54
8.50
18.16
7.80
11.70
15.04
13-30
12.36
5-50
4-92
1.88
2.68
22.50
16.16
19.18
11.12
29-34
27.12
11.30
20.34
18.30
15.78
16.14
8.64
5-20
12.74
11.40
14.50
7.62
4-30
12.80
11.80
12.04
9.02
9.02
5-44
10.56
5.08
10.78
10.94
4-76
3.08
2.62
1.50
2.18
2.00
2.88
1 • 98 j

4-94.
7.08
7.18
8.98
8.74
12.68
10.86
4-38
12.42
22.14
12.04
15.82
21.64
18.60
16.48
12.10
5-34
3-90
5.56
24. SO
14.98
13-12
10.98
21.44
19.46
11.10
14.64
11.98
13-50
7.52
10.20
6.90
9.76
6.10
8.26
3-50
2.90
8.68
8.52
6.78
4-54
4.02
2.74
6.56
5.60
5-34
4-58
4.26
1.86
3-40
1.58
1.50
1.80
1.54
1.30

21.84
20.80
25.60
19.58
19.14
31-52
27.50
16.08
23.64
26.68
26.42
27.68
28.64
19-54
19-34
28.68
18.56
18.10
23.04
21.16
18.86
15.80
17.10
22.18
16.16
16.98
19.04
10.24
14.84
8.56
18.40
16.62
13.78
6.32
9.46
3.46
4-98
12.14
11.16
6.78
4-94
3-8o
3.40
8.18
12.22
4-94
4-44
9.00
2.96
5.62
2.74
1.98
3.14
2.58
2.92

47.68
42.34
44.66
39.62
37-34
33-00
34.58
44-77
34-08
17.22
32.74
26.64
20.76
22.68
26.54
33.92
46.66
47.40
46.76
13-52
17.68
16.02
23.98
15.28
14.10
23.48
22.04
6.10
13.88
11.70
15.88
28.69
16.14
9.06
11.40
6.14
10.84
10.78
8.40
7-44
6.30
7-34
6.50
10.34
12.62
7.68
7.88
21.74
7.60
12.14
6-34
4.80
7.10
7.58
8.70

Clay

Total

21.12 100.74
20.06 100.38
18.42 100.40
24.08 100.38
27.00 100.22
13-08 100.16
14.68 99.98
218.92 99-74
12.76 99.60
9.20 99.82
18.24 100.24
12.26 100.04
7.88 99-54
19-34 100.02
19.52 99.70
13.52 100.16
16.00 100.00
22.12 99.86
17.10 99.62
6.46 100.58
9.96 99.88
14.18 99-74
24.00 100.64
4.46 100.18
10.24 99.72
15.78 100.16
9.70 99.92
5.40 99.84
12.30 99.64
13.88 99.72
10.88 100.20
14.68 99.56
13.22 99-90
16.70 100.08
16.70 100.92
8.72 99.38
15.12 100.50
7.70 99.64
9.26 100.18
6.92 99.84
9.92 100.06
12.10 99.70
10.06 100.04
9.82 100.16
10.60 100.10
11.38 99.84
14.24 99-92
13.82 99-74
15.76 99.96
14.58 99.92
10.60 100.14
9.18 100.12
II-34 99.78
14-50 IOO.16
12.74 :100.78


Method of Expressing Results

Before considering the sieve test figures in the fineness table, reference may be first made to the methods of illustrating and expressing these results.

It is quite obvious that if we have a large table in which are given the per cents of sand retained on each sieve, one may see with little difficulty that some samples run high and others low in fine and coarse grains. Such a tabulation does not permit of quick and accurate comparison, however, and so to make a series of real value some method of representation should be adopted.

This need being recognized, attempts have been made in the past to formulate readily applied and easily understandable methods of expression, some of which are rather widely accepted at present. It would seem, however, that these methods are open to criticism and that a different method of visualizing sieve tests might perhaps lead to a wider application of them.

Average Fineness Figure

One of the common modes of expression is by the use of an average fineness figure, in which by one of several methods a single figure is arrived at that is supposed to express the average size or per cent of fineness of the particles screened. The so-called Scranton method is the most popular and gives an average fineness figure by multiplying the weights of sand retained on each sieve by the mesh of the next larger sieve, taking the sum of the products and dividing by 100. Exactly 100 grams is used, any loss being credited to the middle sieve, and any that does not go through the 20-mesh sieve is credited to a one-mesh sieve.

The following example will more clearly illustrate the method and calculations:

<table>
<thead>
<tr>
<th>Weight of sand passing through</th>
<th>Mesh of the sieve</th>
<th>Mesh of the sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>55.22</td>
<td>100</td>
<td>5522.00</td>
</tr>
<tr>
<td>20.89</td>
<td>80</td>
<td>1671.20</td>
</tr>
<tr>
<td>11.64</td>
<td>60</td>
<td>608.40</td>
</tr>
<tr>
<td>10.57</td>
<td>40</td>
<td>422.80</td>
</tr>
<tr>
<td>1.20</td>
<td>20</td>
<td>24.00</td>
</tr>
<tr>
<td>.06</td>
<td>1</td>
<td>.06</td>
</tr>
<tr>
<td>.42</td>
<td>60</td>
<td>25.20</td>
</tr>
<tr>
<td>100.00</td>
<td></td>
<td>8363.66</td>
</tr>
</tbody>
</table>

Thus 8363.66 divided by 100 gives 83.6 as a per cent of fineness or average fineness figure.
Parmelee\(^1\) has suggested taking the sum of the per cents passing each sieve, and dividing this by the number of sieves used. This gives a figure which may be called the per cent of fineness and serves as an approximate means of comparing sands with each other, provided each has been screened with the same series of sieves.

Ries and Rosen\(^2\) assume an average size for each mesh, and this of necessity makes their method approximate rather than exact. Since it is more accurate than the Scranton Method, however, the following example is given:

<table>
<thead>
<tr>
<th>Sieve mesh</th>
<th>Weight per cent retained</th>
<th>Sieve mesh factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>.0684</td>
<td>.066</td>
</tr>
<tr>
<td>40</td>
<td>.0661</td>
<td>.037</td>
</tr>
<tr>
<td>60</td>
<td>.4009</td>
<td>.019</td>
</tr>
<tr>
<td>80</td>
<td>.6868</td>
<td>.013</td>
</tr>
<tr>
<td>100</td>
<td>.2382</td>
<td>.011</td>
</tr>
<tr>
<td>250</td>
<td>.1256</td>
<td>.007</td>
</tr>
<tr>
<td>clay</td>
<td>.0106</td>
<td>.002</td>
</tr>
</tbody>
</table>

average grain size

\[ \text{I} = 51 \text{ average fineness} \]

In other words, if all the grains in a given volume of the sand, whose mechanical analysis is given above, were reduced to a uniform size, they would pass through a 51-mesh sieve.

Purdy\(^3\) has suggested the use of a surface factor to express an average fineness figure. It is based on the assumption that the surface area of two powders, derived from a unit volume, are in inverse ratio to the average diameter of their grains, and hence the reciprocal of the average diameter is taken as the factor. Although the assumption is in error this factor affords an easy approximation and is sometimes used.

It is obvious that an average fineness or per cent of fineness figure obtained by any of these methods is not accurate because of the necessary assumptions which have to be made. Moreover, because it is an average, such a figure conceals and misinterprets just what it is supposed to make clear — the use to which the sand is best suited.

The main purpose in making sieve tests and separating sands into grades is to give some idea of the venting properties as well as the surface finish that would be left on a casting. For instance,

a fine sand such as a no. 1 Albany is selected because a smooth finish is desired, which would be destroyed by a relatively small percentage of grains on the 20 and 12-mesh sieves. An average fineness figure would totally hide the presence of such grains, especially if the sand should run a little low on the 270-mesh, and would thereby indicate a use for which the sand would not be fitted.

"As an example of this, three sieve analyses are given, the last one of which shows how greatly the percentages on the coarse screens may be increased by increasing the amount on the—270-mesh only 1 per cent. All three analyses have the same average fineness figure as determined by Scranton method."

<table>
<thead>
<tr>
<th>Mesh</th>
<th>No. 1</th>
<th>No. 2</th>
<th>No. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.0</td>
<td>0.10</td>
<td>1.10</td>
</tr>
<tr>
<td>12</td>
<td>0.0</td>
<td>1.00</td>
<td>5.03</td>
</tr>
<tr>
<td>20</td>
<td>0.2</td>
<td>9.70</td>
<td>9.70</td>
</tr>
<tr>
<td>40</td>
<td>0.72</td>
<td>5.76</td>
<td>8.70</td>
</tr>
<tr>
<td>70</td>
<td>19.68</td>
<td>19.60</td>
<td>10.60</td>
</tr>
<tr>
<td>100</td>
<td>20.18</td>
<td>11.30</td>
<td>11.30</td>
</tr>
<tr>
<td>140</td>
<td>14.50</td>
<td>10.50</td>
<td>10.50</td>
</tr>
<tr>
<td>200</td>
<td>8.26</td>
<td>9.22</td>
<td>9.22</td>
</tr>
<tr>
<td>270</td>
<td>9.46</td>
<td>13.50</td>
<td>13.50</td>
</tr>
<tr>
<td>&lt;270</td>
<td>14.40</td>
<td>11.00</td>
<td>12.01</td>
</tr>
<tr>
<td>Average fineness</td>
<td>98.00</td>
<td>98.00</td>
<td>98.00</td>
</tr>
</tbody>
</table>

On the other hand, a coarse sand, such as a no. 4 Albany or a fine Milville gravel, is selected for large castings where easy venting is the important property and the surface finish is only secondary. The presence of a relatively small amount of fine silt will destroy this high permeability and of course an average fineness figure will usually conceal the presence of fine silt.

For these reasons an average fineness figure, when tried on a series of molding sand sieve tests, proves very disappointing. Perhaps a weighted average fineness figure might be used to better advantage. With such a method the percentages on the coarse screens for the fine sands, and those on the fine screens for the coarse sands, would be heavily penalized by some factor so that they would influence the final average fineness figure more than they do with the present methods.

Graphical Methods of Expression

Rectangular coordinates. One of the usual methods of graphically showing a sieve test is to use rectangular coordinate paper, plotting the per cents for each sieve as the ordinate or vertical component against the sieve sizes arranged along the abscissa or horizontal component. Sometimes the per cents are plotted as
Sieve meshes plotted without regard to size of the opening.

Cumulative percentages with sieve openings on logarithmic coordinates

Chart 1 Methods of graphic representation

cumulative in which case the steepness of the resulting curve would give an idea of the character of the sand, a local flattening of the curve meaning a decrease in the percentage of sand on that sieve.

The main objection to using rectangular coordinates for visualizing a sieve test is in the plotting of the sieve mesh sizes. If these sieve sizes are equally spaced, as is the usual custom, all mathematical relation is destroyed because the difference in the size of the mesh opening between, for instance, the 6 and 12-mesh screen is more than 50 times greater than that between the 140 and 200-mesh. In fact, the amount of increase in the size of
opening for each successive sieve varies greatly and therefore it would be incorrect to space equally these sieve sizes when plotting them.

On the other hand, if the sieve mesh openings are correctly plotted according to their real size, the coarse screens will take up all the room, leaving no place adequately to show the per cents of sand held by the finer screens. Since graphical representation should always be mathematically correct, this idea of using rectangular coordinates for the sieve sizes is considered to have doubtful value.
Logarithmic coordinates. In trying to find a satisfactory method of spreading more uniformly the actual sizes of the sieve mesh openings, plotting on logarithmic paper was tried. This gave excellent results, especially if the rectangular coordinates were retained for the vertical plotting of the per cents of sand held by each sieve.

Therefore a combination was used, the actual per cent of sand on each sieve being shown on equally spaced rectangular coordinates, while the actual size of each sieve opening was plotted on logarithmic paper, or, which amounts to the same thing, the logarithms of the actual sizes of the mesh openings were plotted. By so doing, all of the plotting is correct mathematically and formulas can be derived from the plotted curves if it is so desired.

Since using this method the writer has seen a paper by P. G. H. Boswell who described a somewhat similar method of expressing sieve tests. He used, however, a cumulative manner of plotting the per cents of sand, instead of showing the actual per cent of sand on each sieve. It is thought that the method now suggested will give better graphical results for the “area curves” developed in this paper.

The actual size of the mesh openings shown on the following graphs was determined by the United States Bureau of Standards, with the exception of the “through 270,” the figure for which is based on a number of measurements of the grains made with the microscope.

Standard Grades

It is with some hesitancy that this subject is approached as it is realized that although the need of standard grades for molding sands is felt by both foundrymen and producers, many differences of opinion have made it a difficult matter to handle. Because of the widespread use of Albany molding sands, it is perhaps not inappropriate that they should be used to illustrate the plan which the writer desires to suggest.

In the Albany district today there is some difference of opinion among the producers as to just how certain grades should feel to the fingers and thumb. Moreover, certain producers recognize seven or eight grades in contrast to the three or four grades that were established by the pioneer producers. Therefore to be fair to all and yet to outline definitely the limits of a series of grades that will have a practical and widespread use, is something of a problem.

As already stated, all of the producers in the Hudson river district were requested to send in samples of what they considered to be their standard grades. These samples were carefully taken and represent the fingers and thumb knowledge of men who have given a lifetime to molding sand production. After careful sieve tests the results were plotted as previously explained and characteristic curves for each grade soon began to take form. It was then a very easy matter to shift any sample that was out of place to the curve to which it belonged. In other words, every sample was sieve tested and plotted according to the characteristic of its curve regardless of the grade it was supposed to represent. The following table shows the amount of shifting that was necessary.

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Grade as sent in</th>
<th>Grade as plotted</th>
<th>Sample number</th>
<th>Grade as sent in</th>
<th>Grade as plotted</th>
</tr>
</thead>
<tbody>
<tr>
<td>209</td>
<td>00</td>
<td>00</td>
<td>213</td>
<td>1 1/2</td>
<td>1 1/2</td>
</tr>
<tr>
<td>221</td>
<td>00</td>
<td>00</td>
<td>246</td>
<td>1 1/2</td>
<td>1 1/2</td>
</tr>
<tr>
<td>231</td>
<td>00</td>
<td>00</td>
<td>256</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>251</td>
<td>0</td>
<td>00</td>
<td>362</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>253</td>
<td>00</td>
<td>00</td>
<td>365</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>254</td>
<td>00</td>
<td>00</td>
<td>370</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>203</td>
<td>0</td>
<td>0</td>
<td>371</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>206</td>
<td>1</td>
<td>0</td>
<td>204</td>
<td>2 1/2</td>
<td>2</td>
</tr>
<tr>
<td>207</td>
<td>0</td>
<td>0</td>
<td>205</td>
<td>2 1/2</td>
<td>2</td>
</tr>
<tr>
<td>232</td>
<td>00</td>
<td>0</td>
<td>208</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>238</td>
<td>0</td>
<td>0</td>
<td>212</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>240</td>
<td>1</td>
<td>0</td>
<td>214</td>
<td>2 1/2</td>
<td>2</td>
</tr>
<tr>
<td>241</td>
<td>1</td>
<td>0</td>
<td>216</td>
<td>2 1/2</td>
<td>2</td>
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<td>252</td>
<td>3 1/2</td>
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</tbody>
</table>

It might be well to state here that no effort was made to distinguish a no. 2 1/2 or a no. 3 1/2 grade because they were not necessary in the preliminary study and, as explained later, any number of desired grades can be chosen by using the “area curve” charts. Bearing this in mind, an examination of the above table shows that for a no. 2, including a no. 2 1/2 grade, only three samples were placed there that had not already been so graded by the producers; in the no. 3 grade, including a no. 3 1/2 grade, there were no exceptions, and in the no. 00 grade only one sample was out of agreement with the producers grading.
This also tends to bear out the writer's field observations, which are that the finer and the coarser sands seem to be capable of more careful grading by the "fingers and thumb" method than the intermediate ones.

As a whole, the distance that these Albany samples were shifted in the grade series is not considerable and therefore it would seem that the grading recommended is not arbitrary but that it conforms to the grading now in use. In addition, each group contains representatives of open and tight, weak and strong sands, the characteristics of which are reserved for the discussions on cohesiveness and permeability.

Plotting details. Figures 11 to 16 show in detail the amount of material used in establishing the characteristic curve for each grade. Tests on a larger number of sands might have been made but it was considered advisable to use only those which were sent in as representative, so that the final result would be based on actual field experience and selection.

On figure 17 the total plottings for each grade have been averaged and the resultant has been plotted as the average type for each particular grade. In addition, the fine Milville gravel has been added to show how a coarser sand would look graphically.

It should be noticed that these average curves after once crossing the curve of the next coarser grade, never recross. For instance, the average curve for a no. 1 grade crosses that of a no. 1 1/2 grade between the 140 and 100-mesh sieve; from there on the typical no. 1 1/2 sand will always run higher than a no. 1, in the sand held on the coarser screens. This average curve chart also shows clearly the absence of a large amount of silt in the coarse grades and of the absence of any appreciable percentage of coarse grains in the fine grades.

Area curves. All of the foregoing charts were prepared to obtain the data for the "area curves" shown in figures 18 to 20. The upper and lower limits of these shaded areas are plotted directly from the upper and lower limits of the detailed charts of Figures 11 to 16. The heavy average curve line is taken directly from figure 17. Thus we have the typical trend of the curve for any one grade together with the suggested limits of tolerance for that grade.

In analyzing any sieve test to determine the grade of sand represented, it is important to take the entire trend of the plotted curve, so as not to be misled by peculiarities in the per cent of sand retained by any one sieve. By studying this trend or characteristic
Figure 11 Albany 00 grade
Figure 12: Albany No. O grade
Figure 13 Albany No. 1 grade
Figure 14 Albany 1½ grade
Figure 15 Albany 2 grade
ALBANY No. 3

Figure 16 Albany 3 grade
Figure 17. Average curves of Albany grades.
of the curve it is as easy to select a sand that represents a no. \(2\frac{1}{2}\) grade as one that is a no. \(1\frac{1}{2}\) grade, even though a no. \(2\frac{1}{2}\) grade is not separately shown. Any sand which upon being plotted comes about half way between the average curve for a no. 2 and a no. 3 grade could be called a no. \(2\frac{1}{2}\) grade.

In fact, a complete series of grades exists, each overlapping the other, from the very finest imported French sand to a coarse gravel. Thus, since the shaded areas of adjacent grades overlap, with this...
method of graphical interpretation any number of grades and subdivisions are possible, although it is thought the suggested grades are sufficient for a standard of comparison.

Figure 19 Area curve of Albany 1 and 1½ grades

Application. The writer does not have the temerity to suggest any of these “area curves” as standard specifications for any certain type of casting, because the selection of the proper grade of sand is usually a matter of training and foundry practice. For instance, a no. 1 sand is usually used for light castings where a
smooth finish is desired, yet this same sand may be used for large castings if properly opened up with vent wires. On the other hand, some foundries make quite small castings in a no. 2 sand because it is quite permeable, requires no special venting, and will stand the abuse that quantity production entails. In fact, the tendency seems to be to use coarser and coarser sands to be assured of easy venting, and to obtain a good surface finish by applying a special

Figure 20 Area curves of Albany 2 and 3 grades
facing mixture. Hence, although the fine grades are usually used for brass, aluminum and light gray iron work, the medium grades for radiator and bath tub work, and the coarse grades for heavy, large castings, it would seem useless to connect any "area curve" with any particular type of casting except in a very general way.

In the establishing of standard grades for the education of the "fingers and thumb" in the control of field operations, however, it is hoped that these area curves may be of value. Also in the interpretation of sieve tests and in settling disputes over refused shipments, the area curve method is both quick and accurate.

As an illustration, a certain foundry ordered a no. 0 Albany. On receipt, it was judged to be a no. 2 and placed in the bin for that grade. A sieve test of this sand supplied to the writer fits into the no. 2 curve as given in this paper.

One additional advantage, especially to the foundrymen, in the standardizing of molding sand grades, will be the straightening out of the differences in grading between districts. In Kentucky the fine sands are graded as no. 6 and the coarse sands as no. 0, which is just the reverse of the usual practice. Many neighboring districts, while not approaching this extreme, still show quite an appreciable difference in their grading. Is there any logical reason for continuing a no. 6 grade when it does the same work and falls into the same grade as no. 1 Albany? Perhaps it is time that a uniformity of grading between districts is established so that all sands may be described in the same language.

Permeability

Having referred to the grading of the Albany sands according to their fineness, we should consider next their permeability and see what relation it bears to the fineness grades. The table which follows gives the permeabilities of the Albany samples, the tests being conducted according to the standard permeability test devised by the American Foundrymen's Association.

Permeability is the physical property of sand which permits the passage of gases and is ascertained by measuring the rate of flow of air through a standard specimen of sand under a given pressure.

The apparatus used is a simple gasometer which is so weighted that a pressure of 10 centimeters is registered on a manometer tube when the circuit is closed. The time required to pass 2000 cubic centimeters of air through a standard molding sand specimen is noted as well as the back pressure set up in the manometer tube.

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1 For a complete description see Trans. American Foundrymen's Association, June 1924.
This standard sand sample is compacted under easily simulated conditions so that comparable test pieces of the same height, volume and degree of ramming are always obtained.

In this test, permeability is ascertained as the volume of air per minute, per gram per square centimeter pressure, per unit volume in the specimen.

\[
\text{Perm.} = \frac{\text{cm}^3 \text{ of air} \times \text{cm height specimen}}{\text{grs. pressure} \times \text{cm}^2 \text{ area} \times \text{min.}}
\]

Since the amount of air used—2000 cubic centimeters—and the height and area of the standard specimen are always constant, this simplifies to

\[
\text{Perm.} = \frac{501.2}{\text{grams pressure} \times \text{minutes}}
\]

A more rapid method may be substituted by inserting a carefully calibrated gold lined orifice in the apparatus. Then by using a table the permeability may be read directly, thus doing away with the necessity of recording the time required to pass 2000 cubic centimeters of air.

The samples are arranged in grades as determined previously by the area curves. The sixth column gives the maximum permeability and the corresponding moisture content, while the fourth and eighth columns give the permeability on either side of the maximum peak, with the amounts of water used in tempering. In the case of samples no. 206 and no. 263 the maximum permeability persists over a wider range of moisture than the others, and a plotted curve for the permeability would be very flat.

Upon studying this permeability table it is clearly evident that there is a peak for each sand, where with the optimum or "best" water content at from 5 to 13 per cent the maximum permeability is developed. This wide variation in the optimum water would have been expected if the above table had represented a series of tests on sands from many different districts. When it is remembered, however, that these Albany sands all have the same origin and approximate character of bonding material, it is rather surprising.

Of course the amount of bonding material varies with the different samples and the natural explanation would be that the more bond that is present, the more water would be required to temper it. That this explanation is probably the true one, rather than that the character of the bonding material is different, is shown by the fact that all of the sands with low optimum water give a low break in the cohesiveness test, and those with a high optimum water for the maximum permeability are strongly bonded.
more or less water than the optimum. In other sands a difference

This is of practical importance to the foundryman because a sand

with a water variation of 4 per cent shows only a slight change in

It is of interest to notice that some sands show a very sharp
break at the peak with greatly diminished permeability for either
more or less water than the optimum. In other sands a difference
of 4 or 5 per cent of water does not greatly affect the permeability.
This is of practical importance to the foundryman because a sand
with a flat peak will stand more leeway in the tempering control
and cause fewer faulty castings. For instance, sample no. 263
with a water variation of 4 per cent shows only a slight change in
permeability, in contrast to sample no. 257 which shows a very sharp
drop off in permeability from the maximum with a very slight
change in the tempering water.

Coming now to the relation of permeability to the fineness or
grade of a sand it might be well to point out that this relation is
influenced by the shape, size and arrangement of the sand grains.
Since all of the Albany sands are sub-angular in grain outline, the
effect of the shape is not very important in this instance. The size
of the sand grains, however, directly affects the permeability as it is
obvious that appreciable percentages of fine silt will clog up the
pore spaces and hinder the passage of gases.

This is well illustrated by the following examples which are out
of alignment with the usual permeabilities of their grade, and which
would be considered very close, tight sands for that respective grade.
That this low permeability is due to fine silt is evident. In fact, in
the final averaging of the permeabilities for each grade these three
samples were disregarded.

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Grade</th>
<th>Maximum permeability</th>
<th>Average permeability for that grade</th>
<th>Per cent</th>
<th>Average per cent —270 for that grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>362</td>
<td>1½</td>
<td>13.8</td>
<td>30</td>
<td>28.7</td>
<td>12.0</td>
</tr>
<tr>
<td>363</td>
<td>2</td>
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<td>21.7</td>
<td>9.4</td>
</tr>
<tr>
<td>217</td>
<td>3</td>
<td>50.0</td>
<td>200</td>
<td>12.1</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Hence it has been the usual practice to connect low permeability
for any grade with the presence of a large amount of clay and fine
silt. As far as the presence of the clay bond is concerned, this idea
is not correct, since with proper tempering, the bond will uniformly
coat the sand grains and not clog up the pore spaces. An example
of this may be seen in the Milville gravels which are often strongly
bonded but which give permeabilities of 800 to 1000.

Indeed it is sometimes unfair to attribute low permeabilities to
the presence of fine silt as in each grade group there are samples
with higher permeabilities than similar ones in the same group
which have even less clay and fine silt. The following table groups
the samples by twos for comparison and in each case it is seen
that the sample with the larger amount of clay and silt — minus 270
— has the higher permeability.
In the above samples it would seem that the arrangement of the sand grains and the per cent of each size are more influential than the amount of silt present. Whenever there is sufficient diversity of grain size so that there are enough particles of any one size to fill the interspaces between those of the next larger size, the sand will have a lowered permeability and a smoother, more regular fineness curve.

**Grading of permeability.** The range of permeabilities for molding sand is very wide, starting with about 5 for the finest sands and increasing to over 1000 for some of the Milville gravels. It has been the usual custom to speak of high, low and medium permeabilities by roughly dividing this entire range of from 5 to over 1000, without considering the fineness grade of the sand, yet in actual practice the grade of the sand and the permeability are closely linked together. Foundrymen usually change their order to a coarser grade simply to obtain increased permeability. Moreover, in placing an order, for instance, for a no. 2 molding sand, an open sand is often specified since for each grade of sand there exists high and low permeabilities.

Therefore, since permeability is so intimately associated with the fineness grading of molding sands, both from a practical as well as from a theoretical viewpoint, it is considered advisable to think of permeability in terms of the grades.

With this in mind the following table was prepared to show the usual permeabilities for each grade of Albany molding sand. It is realized that there will be considerable overlapping of values as,
for instance, an open no. 1$\frac{1}{2}$ sand might have a higher permeability than a close no. 2, but even so this overlapping will not be harmful and will merely tend to show the sand in its true relation.

<table>
<thead>
<tr>
<th>Grade number</th>
<th>Low permeability</th>
<th>Medium permeability</th>
<th>High permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>5</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>0</td>
<td>7</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>1$\frac{1}{2}$</td>
<td>10</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>200</td>
<td>300</td>
</tr>
</tbody>
</table>

By inserting a no. 2$\frac{1}{2}$ grade, which can be very easily done from the "area curves," the large jump between the no. 2 and no. 3 grades would be remedied. In fact, this method of grading permeabilities is just as elastic as the "area curve" method with which it goes hand in hand. Thus a permeability of 13 would be considered high for a no. 00, medium for a no. 0, and low for a no. 1. A permeability of 13 by itself without the grade being given would have little meaning.

This method of grading permeabilities is offered merely as a suggestion as it is realized that in order to have this widely accepted it will be necessary to study sands from other districts. Even with tentative limits such as suggested above it is hoped that the permeability figure will mean more and have a wider use among foundrymen and producers.

**Cohesiveness or Bonding Strength**

The bonding strength of the Albany molding sands was determined in accordance with the standard method recommended by the joint molding sand research committee.¹

This method is as follows:

Twenty-five hundred grams of dry molding sand are carefully tempered with the desired amount of water and allowed to stand 24 hours in an air-tight container. At the end of this period be sure there are no dry lumps or other evidences of uneven tempering. Obtain the moisture content accurately by drying 100 grams of this tempered sand for one hour at 105° C.

¹ For a complete description see Trans. American Foundrymen's Association, June 1924.
<table>
<thead>
<tr>
<th>Sample number</th>
<th>Grade as plotted</th>
<th>Per cent water</th>
<th>Cohesiveness</th>
<th>Per cent water</th>
<th>Maximum cohesion</th>
<th>Per cent water</th>
<th>Cohesiveness</th>
<th>Per cent clay</th>
<th>Through 270</th>
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</thead>
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*Too dry.

Take 1000 grams of tempered sand. Shake this sample into the standard mold box, the bottom of which is covered with thin waxed paper, strike off level, and adjust the side pieces.

The sand in the mold box is given three rams with a 20 pound weight dropped from a height of 16 inches. The molded bar is removed, still resting on the waxed paper and metal base plate, and placed in the breaking apparatus. This latter is a motor device that pulls the waxed paper and molded bar at a uniform rate of
6 inches a minute over the end of the base plate. When the weight
of the overhanging section of the bar causes it to break, this broken
segment is caught and carefully weighed in grams. Repeat this
operation until as many breaks are obtained as the bar will yield.

Manifestly the thicker the molded bar, the larger the broken seg-
ment and so it is necessary to make all bars uniform, with a thick-
ness of 1 inch. If the molded bar, therefore, does not have a
standard thickness of 1 inch, a new bar must be made and either
more or less than 1000 grams of tempered sand taken so that the
final thickness will be at least within .03 of the 1 inch standard.

Enough bars should be made and broken so that at least six,
broken segments are obtained, from not less than two bars, the
average of the breaks of each bar, showing a variation of not more
than 5 per cent from the average of the two bars.

The bonding strength is expressed directly in grams.

The accompanying table gives the bonding strength for the dif-
ferent sands as grouped according to the area curve method. The
second double column gives the maximum bonding strength and
the first and third double columns give the bonding strength with corresponding moisture
contents, on either side of the peak.

These results of the cohesiveness test indicate a peak or maximum
strength for each sample with one certain water percentage of tem-
pering. This optimum or "best" water of tempering for cohesiv-
eness often does not coincide with that of the maximum permeability,
although the same physical forces are doubtless in control in both
cases. This matter is taken up briefly when considering the relation
of water to permeability and bonding strength.

In this connection it might be well to point out here that over
half of the Albany sands develop their best strength with about
6 per cent of water, which should be contrasted with the usual
7.5 to 8.5 per cent of water for their best permeability. This gives
the foundryman some option in tempering his Albany sand so as to
bring out that property which he most desires.

Because of the nature of the test, the cohesiveness figures are
not as accurate as those determined for the permeabilities. For
this reason the peaks of the curves for the maximum cohesiveness
are inclined to be flat and should be depended on only in a general
way. With many sands from other districts, where the character
of the bonding material is different, this maximum cohesiveness is
developed more sharply and a loss of strength results with a very
slight change in tempering. With most Albany sands, however, a
change of 2 or 3 per cent in the amount of water does not seem to make much difference in the strength, as long as the sand is not undertempered.

Comparing the Albany sands as a whole with molding sands in general, the lower average strength of the bond is an outstanding characteristic. Strong molding sands have a cohesiveness figure of 300 to 400 which is in decided contrast to 200 to 250 for the stronger Albany sands. A typical Albany sand will average between 150 and 200 grams cohesiveness which is about a medium bonded sand.

It would seem at first thought that so weak a sand would not resist the cutting action of molten metal or would not faithfully reproduce intricate molding shapes. Yet Albany sands are noted for good performance in these respects. It has been claimed by some investigators that the reason for this lies in the subangular character of the Albany sand grains, since this type withstands cutting action and transmits molding pressure easily. In fact, a subangular grain tends to interlock and form a good face with a surprisingly small amount of bonding material.

As to this amount of bonding material it is thought that the figures given for the percentage of "clay substance" are not as significant as they might be since they contain unknown amounts of fine silt and inert material that are not true colloids and have no bonding action. It might be well to further separate this "clay substance" by elutriation when making a sieve test, or the dye test might help to give a better idea of the true character of this bond.

Grading of cohesiveness. Even with the "clay substance" percentages in their present unsatisfactory form it is evident that the grading or fineness of the sand enters into the real bonding strength of the sand only in a minor way. The real controlling force is the character and amount of the bonding material. That is, we can expect to find just as strong sands in the coarse grades as in the finer grades, if there is sufficient bonding material present to coat all the sand grains. It is true that we find more strong fine Albany sands than strong coarse Albany sands, partially because the fine sands present a larger surface area, but practically, the grade of the sand does not make much difference.

A glance at the cohesiveness table for Albany sands would seem to confirm this. In addition, 200 molding sands from many different states and districts, representing all grades from a very coarse gravel to the finest sand, show this same disregard of the effect
of grain size. Therefore it is suggested that the grading of the bonding strength should not be connected in any way with the fineness grading but should be expressed separately.

In the following table there is suggested a terminology that might be used to express bonding strength, as well as the strength ranges to which each might apply. The third column gives the percentage of 200 samples of all grades, which fall into each group.

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Tentative limits of strength</th>
<th>Per cent of occurrence</th>
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<tbody>
<tr>
<td>Extra weak</td>
<td>Below 80</td>
<td>0.0</td>
</tr>
<tr>
<td>Very weak</td>
<td>80-100</td>
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<tr>
<td>Medium</td>
<td>150-200</td>
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<tr>
<td>Medium strong</td>
<td>200-250</td>
<td>21.4</td>
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<tr>
<td>Strong</td>
<td>250-300</td>
<td>13.1</td>
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<tr>
<td>Extra strong</td>
<td>400-500</td>
<td>1.3</td>
</tr>
</tbody>
</table>

As should be expected, over 50 per cent of the molding sands fall into the medium to medium-strong group. Those below 80 are usually too weak and require the addition of a binder, while those above 400 are usually too strong and have to be opened up to vent satisfactorily.

THE RELATION OF WATER TO THE BONDING STRENGTH AND PERMEABILITY OF MOLDING SANDS

In former times, and even to a considerable extent at present, the amount of water required for tempering a sand has been left largely to the judgment of the molder or foundry foreman. There are now an increasing number of foundries, however, where the water content of the sand is closely controlled because it is realized that certain defects in castings are traceable to an incorrect moisture content. This of course is due to a recognition of the facts that all sands do not temper alike and that each one gives the best results with one certain water content. Lack of knowledge of these facts has no doubt sometimes resulted in a new sand being condemned because it was tempered with the wrong amount of moisture.

The cause of the variation in bonding strength and permeability with changing water content is a matter of great interest as well as practical value and an attempt is here made to explain this.

At first glance it would seem as though the former practice of adding just enough water to make the sand cohere, is correct, but

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with the recently devised standard testing methods it has been demonstrated that many sands reach their best strength and permeability with the addition of 2, 4 and even 6 per cent of water above the point where formerly they might have been considered correctly tempered.

This additional water does not appear to clog up the pore spaces and make the sand tight as claimed by some foundrymen, but in reality, up to a certain point, opens it up.

The Bond

Undoubtedly the bonding strength is a very important and not thoroughly understood property of molding sand. Yet the presence and behavior of this bonding material is the criterion that distinguishes molding sand from all other sand. Its destruction by burning out during casting immediately returns the sand to the waste heap, a molding sand no longer. Too much bond, too small an amount of bond, the wrong kind of bond or the improper tempering of the bond, are undoubtedly the daily causes of foundry losses. In fact, for this reason foundrymen have become skeptical of drawing on new and untried sources of supply.

That the bonding material is not necessarily clay has been appreciated for some time, yet the terms "clay bond" and "clay substance" are still rather widely used. Our present knowledge tends to show that this bond is usually a mixture of oxides and hydroxides of iron, alumina and silica in a state of extremely fine division. We call these colloids and think of them as having a netlike or spongy arrangement with the inherent ability to take up many times their volume of water.

Upon subjection to high heat these colloids are destroyed, the ability to take up water and become sticky is lost, and the sand is said to be "deadburned" and is usually thrown away. Fortunately at a temperature somewhat below the complete dehydration of these colloids, no marked effect seems to be produced. Thus if the bond is not subjected to too high a heat it will rehydrate, become sticky again and can be used again.

It is this important critical temperature, which varies for each type of colloidal bond, that doubtless makes some sands stand up better than others under foundry conditions. Many clay bonds will stand a relatively high temperature without breaking down but they have the unfortunate property of partly sintering and in this condition the colloidal nature of taking up water and forming a sticky mass is lost. Fine grinding will often restore it.
other hand, a hydrated iron bond will rehydrate better than any other type although very high temperatures are unfavorable to its use. A happy combination of hydrated colloidal iron and clay, such as the chemical analyses of Albany sands show, gives a long lived bond, one that will easily take up water.

**Arrangement of the bond.** Many molding sands seem to have the bond existing in two forms since after repeated washings of the sand grains and even treatment with dilute hydrochloric acid, a thin pellicle of iron oxide still remains, giving the sand grains a rusty tint. This film would appear to be dehydrated and incapable of taking up water or dye solutions. C. W. Holmes\(^1\) has remarked on a two-form existence of the bond and speaks of:

1. A mobile or hydrated bond which is capable of transference from one sand grain to another.
2. A static bond which is fixed to the surface of the sand grains and forms a hold upon which the mobile bond may be easily spread and displayed to the best advantage for mechanical strength.

Many molding sands, as for example some of the Albany sands, show this two-fold characteristic of the bond. A small amount of the static bond has a greater tendency to strengthen a sand than several times that amount of mobile bond on smooth grains of silica. This is one reason why an artificially blended molding sand of loam and clean silica grains often does not have the feel of a natural product and will give clean sand grains upon washing.

**Effect of water on the bond.** When the molding sand is dry most of the bonding material lies loosely in the interstices between the sand grains. Thus the permeability of a dry molding sand is low because of the clogging up of the pore spaces and of course, since the bonding material is not sticky in this condition, the cohesiveness is low also.

With the addition of water the mobile part of the bond becomes sticky, swells up and wraps itself around the sand grains, thus moving out of the pore spaces. Naturally both the permeability and cohesiveness increase. Therefore, with just the right amount of water the bond will be evenly spread around the sand grains, leaving the pore spaces free for easy venting, and because of its sticky character with this amount of water, the cohesiveness will also be high.

If too much water is added the bond will not be able to take care of it and free water will fill the pore spaces. The bond will also become weaker, just as an overtempered green clay brick does.

\(^1\)C. W. Holmes. Iron and Steel Inst., September 1922.
and slide from the sand grains back into the pore spaces. It is therefore evident that too much water will decrease both the cohesiveness and permeability of molding sand and is just as great an evil as too little water.

It is interesting to note here that many molding sands, when correctly tempered, will dry out completely without the sand grains changing position. This was proven by 15 and 20-minute exposures of tempered molding sand to the photographic light, during which time the bond dried out completely without any evidence of movement on the photographic plate. This is rather remarkable when it is remembered that the bond had swelled up and expanded during tempering. If the sand had been much overtempered, so that free water existed in the pore spaces, doubtless a shrinkage movement would have spoiled the negative.

Under the microscope this movement of the bond upon the addition of water, is very clearly seen, so that the critical point of correct tempering can be determined very easily and quickly in this manner. Indeed it is quite possible that some day the microscope may serve as a very efficient agent in foundry control work and obviate some of our present more cumbersome methods.

In order to show this graphically a few photo-micrographs are here presented but it should be understood that much of the detail has been lost. Really to appreciate this action of the water on the bond and permeability, a comparison eyepiece and two microscopes should be used so that the details of the arrangement of the grains due to differences in water content, can be seen side by side.

A recent paper by Dietert\(^1\) gives in some detail the proper methods to use in taking photo-micrographs of molding sand, but for the following illustrations a simple inclined illumination was used with an ordinary microscopic lens, the time of the exposure often lasting over 15 minutes. With stronger illumination, a longer focus lens and an iris diaphragm, better results would have been secured.

Figures 21 to 23 represent a no. 3 Albany sand tempered with increasing amounts of water to show how the grains agglomerate. This sand is not compacted but is loose, being taken from the different tempering piles. More compounding of the grains is noticeable with each increase of the water content.

As a final illustration, figures 24 to 26, are presented as especially representative of this reaction of a molding sand with

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Figure 21 Albany no. 3. Six per cent water. x 17.

Figure 22 Albany no. 3. Eight per cent water. x 17.
Figure 23 Albany no. 3. Ten per cent water. x 17.

Figure 24 Sample 217. Six per cent water permeability 10. x 16.
Fig. 25 Sample 217. Eight per cent water. Permeability 50. x 16.

Figure 26 Sample 217. Ten per cent water. Permeability 36. x 16.
insufficient, correct and excess amount of water of tempering. These pictures were made on the compacted surface immediately after determining the permeability. The grainy, rough appearance of the undertempered sand in figure 24, and the overtempered sand in figure 26 with its large per cent of bond-free sand grains are in striking contrast to the evenly coated, nicely arranged condition of the sand in figure 25, which has been correctly tempered. In fact, these three photographs are so entirely different that it seems almost impossible that the same Albany sand, the same compaction and the same enlargement are common to all.

Relation of Water to Strength and Venting

Coming now more directly to the relation between the bonding strength and permeability, when a molding sand is tempered with varying amounts of water, one of three alignments is usually developed.

1. The maximum bonding strength is developed with the same amount of water as the maximum permeability; that is, the peaks of their plotted curves agree.
2. The maximum bonding strength is developed with less water than the maximum permeability.
3. The maximum bonding is developed with more water than the maximum permeability.

Before considering these three relations further it should be pointed out that the permeability test is more delicate than the cohesiveness test and therefore some disagreement in the alignment of their curves may be attributed to this fact. This is especially true with certain sands where the cohesiveness does not seem to change much, even with quite a variation in the amount of tempering water.

Moreover, the cohesiveness test is handicapped in not being able to give consistent breaks for those sands that require only a small amount of water to develop their strength. This may perhaps be due to a nonuniformity of tempering when such small amounts of water are used, but even with special care, the bars tend to flaw and give unreliable results. Very likely if the above disturbing factors did not exist more Albany sands would come under class 1, as they might perhaps develop their best permeability and strength with one and the same per cent of water.

Considering the Albany sands tested we find that 27 per cent of them fall in class 1 and show an agreement of the permeability and cohesiveness; 68 per cent come under class 2, that require
less water for the maximum cohesiveness than for the maximum permeability; 5 per cent represent class 3 and require more water for the best cohesiveness than for the best permeability.

The photographs already presented give a general idea of the movement and arrangement of the bonding material and show why there should be a rise and fall in the values of both the permeability and cohesiveness. For a more adequate explanation, however, it would seem necessary to consider the influence of the grading of the sand grains and the amount of fine silt as well as the character of the bonding material.

Taking up each one of the three general classes already outlined, an attempt will be made to explain the conditions existing and their effect on the cohesiveness and permeability. These explanations are offered as suggestions merely, as it is thought that the investigation of the effect of water on molding sand has not yet reached the stage where entirely trustworthy conclusions can be drawn.

**Class 1, optimum water content the same for cohesiveness and permeability.** This agreement in tempering for cohesiveness and permeability is not restricted to one certain water content but may occur with any amount of from 3 to .13 per cent, depending on the particular sand. It is as prevalent in fine brass sands as in coarse sands, in strongly bonded sands as in the weaker sands, and sands with either high or low permeability seem to exert no restrictive influence. Thus any grade of molding sand may come under this general class if it has the right kind of bond.

By the right kind of bond is meant material of such a nature that with the proper tempering water, the sand grains are uniformly and evenly coated. With less than the proper amount of water the bonding substance is not evenly distributed, the coating around the grains will be uneven and grainy in appearance, the greatest cohesiveness will not be developed and some of the bond will be left in the pore spaces, giving a lowered permeability.

With the correct amount of tempering water, because of the resulting even coating around each grain, the greatest amount of bearing surface will be formed and the maximum cohesiveness developed. At the same time, the largest amount of pore space will be left open and the best permeability developed.

An excess of tempering past this point will soften and weaken the bonding material and tend to permit it to flow back into the pore spaces. Obviously the permeability and bonding strength will then both decrease, although not necessarily at the same rate.
Class 2, maximum cohesiveness is developed with less water than the maximum permeability. That the maximum cohesiveness is developed with less water than the maximum permeability is perhaps due to the difference between the adhesive and cohesive properties of the type of bond that is common to sands of this group. That is, the bonding material would tend to lose its coherence or ability to stick together and resist rupture before it would lose its adhesiveness or ability to coat the sand grains.

With such an explanation, the addition of water would tend to give a break between the bonding particles long before these particles lost their ability to adhere to the quartz sand grains. As long as the bonding material remained on the sand grains and soaked up the tempering water, the permeability would not start to decrease, even though the maximum for the cohesiveness had been passed.

From a previous study with dye solutions it is thought that the colloidal bonding material in this group of molding sands is mainly of a basic nature and therefore would tend to be adsorbed by the unlike acid quartz grains. Some such explanation must be advanced to explain the wrapping of the bonding material around these grains upon the addition of water, irrespective of which one of the three general classes is being considered.

In this connection it may be of interest to mention that during the microscopic study of the effect of water on Albany sands, it was noticed that feldspar particles, especially if weathered, took up very little if any bonding material, irrespective of what tempering was used. Hence it is thought that the property of adherence is a very important one and that the arrangement of the bonding material around the sand grains is very likely due to colloidal adsorption.

Class 3, the cohesiveness requires more water to develop a maximum than the permeability does. Only 5 per cent of the Albany sands show such a relation, although a large number of silty core sands, which were studied at the same time, show this same tempering peculiarity. That such a condition is unusual is evidenced by the fact that the total per cent of occurrence is very small.

In a silty core sand the small amount of bonding material present would be immediately overtempered by the addition of water and therefore the pore spaces would become clogged with water and fine silt and the permeability would show a continual decrease. The small increase in cohesiveness with the addition of water could be attributed to the dampening action and increased surface tension.
For a true molding sand of this class 3, sample 241 might serve as an illustration. The explanation of the reaction of this peculiar type of molding sand to water is difficult. A small amount of "clay substance" and a relatively large amount of minus 270 mesh are often typical of this group and are therefore suggestive. Perhaps the real explanation lies in a large per cent of inert material that is often included in the so-called "clay substance."

If there happens to be a large amount of such inert material, then the active bonding colloids would be quickly overtempered upon the addition of even a small amount of water. The further increase in cohesiveness upon the addition of water, linked with a usual constant decrease in permeability, might be attributed to the surface tension of the water on the sand and silt grains. The finer the grain size, the more effective this surface tension seems to be.

Of course one could say that the adhesion of the bond to the sand grains was not very strong, and that the best cohesion of the bonding particles to each other requires a lot of water. Perhaps an acid type of colloidal such as hydrated colloidal silica, in contrast to the usual basic type of colloid, might be the solution of this low adhesion to the acid quartz grains and the relatively high optimum water for cohesive strength.

SUMMARY OF RELATION OF WATER TO STRENGTH AND PERMEABILITY

It is evident that the best sands for foundry practice are those that develop their maximum cohesiveness and permeability with the same amount of tempering water. Among such sands certain ones show a relatively small variation in both permeability and strength over quite a range in the amount of tempering water. Such sands are ideal and will stand the abuse that quantity machine production entails.

Other sands of this class show a rapid change in either the permeability or cohesiveness, or sometimes in both, with a small variation in the water content. These sands require careful watching so that the tempering of the heaps may always give the best results.

Those sands which develop their maximum cohesiveness with one amount of water and the maximum permeability with another always present something of a problem, as the choice must be made as to which of these physical properties to sacrifice, especially if there be several per cent difference in their optimum water contents.
USES OF ALBANY SANDS

Albany molding sands are used by more nonferrous and malleable foundries than any other sand in the United States. Grades indicated as no. 00, no. 0 and no. 1 are preferred for nonferrous work. They are shipped as far west as Tacoma, Wash., for brass and as far as Milwaukee for malleable castings.

As already explained, the finer grades are used for small castings where a smooth finish is desired, while the no. 2 and no. 3 grades are used for larger castings where high permeability is important. The following table gives an approximate idea of the use to which each grade is usually put.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 00</td>
<td>Low permeability and used only for the smallest castings where a smooth finish is essential</td>
</tr>
<tr>
<td>No. 0</td>
<td>Small brass, aluminum and gray iron castings; an admirable stove plate sand</td>
</tr>
<tr>
<td>No. 1</td>
<td>For the average casting of from 5 to 75 pounds</td>
</tr>
<tr>
<td>No. 1½</td>
<td>For large brass and aluminum castings and for gray iron of from 50 to 200 pounds</td>
</tr>
<tr>
<td>No. 2</td>
<td>Gray iron from 150 to 300 pounds</td>
</tr>
<tr>
<td>No. 3</td>
<td>Gray iron from 300 to 600 pounds</td>
</tr>
<tr>
<td>No. 4</td>
<td>Gray iron from 500 to 1000 pounds and over</td>
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It should be remembered that by using vent wires in the fine grades and a smooth facing mixture for the coarse grades, the tolerance limits of the above table are entirely upset. For instance, with proper precautions a no. 1 sand may be used for 200 or 300-pound castings while a no. 2 sand may give satisfaction in 25 or 50-pound work.
<table>
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<th>Clay subs.</th>
<th>Dye absorp.</th>
<th>Water per cent</th>
<th>Bond at.</th>
<th>Perm.</th>
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*These samples are from different parts located between Clays Pumps and Phases. The grade numbers are those of the producer.*
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The grades numbers are those of the producer. Poughkeepsie.

These samples are from different pits located between Glen Falls and Poughkeepsie.

ALBANY MOLDING SANDS OF THE HUDSON VALLEY
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<td>7.40</td>
</tr>
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</table>

These samples are from different pits located between Clays Falls and

The grade numbers are those of the producer.
| 253 | 00 strong | .20 | .12 | .22 | .62 | 1.28 | 5.56 | 8.74 | 19.14 | 37.34 | 27.00 | 100.22 | 336 |
| 254 | 00-J | .26 | .12 | .32 | .86 | 2.44 | 5.88 | 12.68 | 31.52 | 33.00 | 13.60 | 100.16 | 272 |
| 258 | 00-P | .16 | .22 | .40 | 2.32 | 1.36 | 2.68 | 5.56 | 23.04 | 46.76 | 17.00 | 99.62 | 304 |
| 261 | 0 strong | .04 | .08 | .20 | 1.30 | 3.16 | 7.58 | 10.86 | 27.50 | 34.58 | 14.68 | 99.98 | 244 |
| 203 | 0 | .30 | .38 | .18 | .30 | 2.12 | 4.92 | 8.50 | 12.42 | 23.64 | 34.08 | 12.76 | 99.60 | 276 |
| 211 | 0 open | .12 | .04 | 1.04 | 24.68 | 21.94 | 18.30 | 11.98 | 10.24 | 6.10 | 5.49 | 99.84 | 276 |
| 238 | 0 | .04 | .02 | .12 | .62 | 2.20 | 7.80 | 12.40 | 26.42 | 32.74 | 18.24 | 100.24 | 336 |
| 244 | 0 open | .02 | .02 | .02 | 2.48 | 4.02 | 13.30 | 18.60 | 19.54 | 22.68 | 19.34 | 100.02 | 276 |

*Appeared wet.*
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<td>.05</td>
<td>.04</td>
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<td>304</td>
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</table>

Notes:
- Grade if used:
  - 0 strong
  - 0
  - Albany No. 2
  - Albany No. 2-W

- Locality:
  - 0 strong: between Glen Falls and Poughkeepsie
  - 0
  - Albany No. 2
  - Albany No. 2-W

- These samples are from different pits located between Glen Falls and Poughkeepsie.
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<th>Albany No. 2-NR</th>
<th>Albany No. 2 open</th>
<th>Albany No. open</th>
<th>Albany No. open</th>
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These samples are from different pits located between Glens Falls and}

The grade numbers are those of the product
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<td>Too dry</td>
<td>9.4</td>
<td></td>
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</tr>
</tbody>
</table>

NEW YORK STATE MUSEUM
|     | Albany No. 3½ | .60 | .74 | 2.46 | 1.94 | 61.00 | 4.40 | 1.98 | 1.30 | 2.92 | 8.70 | 12.74 | 100.78 | 244 |
|     |              | .20 | .92 | 1.82 | 10.02 | 10.54 | 6.80 | 12.90 | 12.96 | 13.48 | 15.40 | 15.20 | 100.24 | 304 |
| 367 | No. 4........... | 2.14 | 3.42 | 13.60 | 11.96 | 7.86 | 12.20 | 10.82 | 12.74 | 14.50 | 10.92 | 100.16 | 544 |
| 368 | 5 R. L............... | 2.7 | Too dry | 12.2 | 5.0 | 158 | 55.0 | 7.0 | 129 | 173.0 | 9.3 | 96 | 162.0 | 304 |
|     |              | .5 | Too dry | 11.8 | 5.0 | 197 | 11.8 | 7.1 | 176 | 19.0 | 9.2 | 163 | 20.0 | 544 |
|     |              | 11.5 | Too dry | 15.7 | 11.5 | 100 | 15.7 | 11.5 | 100 | 15.7 | 11.5 | 100 | 15.7 | 544 |

*Too dry.*
STATISTICS

Incomplete returns show that the value of the molding sand now produced in the State mostly from the Albany district amounts to over three-quarters of a million dollars yearly. Following is the yearly production in short tons from 1908 to 1923:

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<th>Tons</th>
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<td>579 999</td>
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<td>731 896</td>
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FUTURE DEVELOPMENT

From the field work it would seem that the largest undeveloped territory lies northward and it is in this direction that the greatest amount of future prospecting will be carried on. A large amount of sharp, open sand exists toward Glens Falls and beyond, but scattered through this are many molding sand deposits. In addition, new molding sand deposits are known to exist alongside of present operations and these will also be opened up as conditions warrant.

Formerly the molding sand was hauled by teams to the nearest railroad and either temporarily placed in stock piles or shipped immediately. Today this same custom prevails, although trucks have in many cases been substituted for teams and barge shipments for rail transportation. With the continued development of the New York State Barge Canal the shipments by water should become of more importance.

Between 150 and 200 acres of land are yearly stripped of their molding sand at the present rate of production. Since this stripped land will not furnish further molding sand for several thousands of years, it is evident that the Albany sands are not inexhaustible. To offset this depletion the haulage distance is being increased all the time but even with improved roads and large trucks the profitable distance would appear to be limited to about 3 miles.
With the continued establishment of foundry control methods of testing, the producers will doubtless have to meet more rigid specifications. In order to hold their customers this will result in a more careful inspection at the molding sand banks. In fact it is not improbable that a price premium will be asked for this carefully selected sand, especially if it is more strongly bonded or finer in grade than the average run of the district.

The elimination of the less skilful producers and the further training of all the foremen in the recognition of standard grades are the outstanding requisites for the production of better Albany molding sand on a commercial scale.
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BY
C. R. Crosby and Sherman C. Bishop

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STUDIES IN NEW YORK SPIDERS

Genera: Ceratinella and Ceraticelus

BY

C. R. Crosby and Sherman C. Bishop

INTRODUCTION

For many years we have been collecting spiders in all parts of New York State for the purpose of determining the range of each species and thereby obtaining indications of the faunal life zones of the region. In this work it is of greatest importance to determine accurately the species under consideration and in order to do this we have found it necessary to revise many of the genera, particularly in the Erigoneae group. In this paper we present the results of studies of two of these genera, Ceratinella and Ceraticelus.

The preparation of most of the drawings, by Albert W. Force of Ithaca, N. Y., was made possible by a grant from the Heckscher Research Foundation at Cornell University. Because of serious illness, Mr Force was unable to complete the work and the rest of the drawings were made by Walter J. Schoonmaker of the State Museum staff.

The material on which this study is based is to be found principally in the collections of the Department of Entomology of Cornell University and the New York State Museum. The types of the species described by J. H. Emerton and Nathan Banks have been studied in the Museum of Comparative Zoology at Cambridge, Mass. We are indebted to Dr R. V. Chamberlin for the loan of many specimens, to J. H. Emerton for specimens and the critical examination of material and to Professor William M. Barrows for material from Ohio.

In the study of the palpal organ it was found expedient to make use of a few new terms. In this group the tegulum is usually greatly widened on the lateral side, when the parts are in the normal position,
and this widened part we have designated as the *bezel* (figure 4b). The embolic division of the bulb is of the spiral type and is attached near its middle. The part nearest the base of the tarsus hangs free as a flattened, curved process. This we have called the *tailpiece* of the embolic division (figure 4t). The *tip* of the tailpiece is free and the *base* is near the point of attachment. The apical part of the embolus is that part which extends from the point of attachment to the tip. In some species the ejaculatory duct is free and leaves the supporting embolus before the tip. We have restricted the term *embolus* to the chitinized support and have considered the duct separately when the terminal part is free.

**Ceratinella** Emerton

Conn. Acad. Trans. 6:32. 1882

Type: *Theridium breve* Wider

This genus was established by Emerton in 1882. The name stands alone as a center heading without the words, "new genus," elsewhere appended to the names when new genera are established in this paper. Below the name and above the description stands the line:

"Ceratina Menge, Preussische Spinnen."

This is given in the same form as are references to previous descriptions throughout the paper.

*Ceratina Menge* (1867) was preoccupied by Latreille in the Hymenoptera (1804) and Simon (Ar. Fr., 5:595. 1884) assumed that Emerton has proposed the name Ceratinella to replace it. He also considered that all the species which Emerton at that time placed in Ceratinella, with the exception of *C. brunnea* Em. were not congeneric with *Theridium breve* Wider which he at the same time designated as the type of Ceratinella and he therefore proposed for these species the genus Ceraticelus. Later (Hist. Nat. Ar., 1:651. 1894) he designated *C. fissiceps* Cambr. as the type of Ceraticelus. Banks (Jour. N. Y. Ent. Soc. 1:130. 1893) considering that Emerton did not propose Ceratinella to replace Ceratina but rather to designate the species which he placed under it, proposed Ceratinodes for Menge's genus and has since retained the name Ceratinella for the American species, but in his Catalogue (Bul. U. S. Nat. Mus. 72, p. 25. 1910) he places *C. brunnea* Em. in Ceratinella. This would indicate that he considers that the two genera should be reunited. Emerton in his later papers seems to hold to this view since he uses Ceratinella for all the American forms including *C. brunnea* Em. Cambridge, however, (Ann. Mag. Nat. Hist. [ser. 7], 11:44. 1903) considered that this was not a case of the definite substitution of one name for another, as Simon held, but a new genus was founded with definite species quoted under it. In spite of this he nevertheless accepts as the type of Ceratinella, *Theridium breve* Wid. on the designation
of Simon, although this species was not originally included in the
genus by Emerton.

The internal evidence from Emerton’s 1882 paper clearly sub-
stantiates Simon’s view that Ceratinella was proposed to replace
Ceratina Menge, preoccupied. The other question, as to whether
C. brevis is congeneric with C. fissiceps is not so easily
settled. From a study of the species related to these forms we are
inclined to believe that they represent natural groups, closely related
it is true, but capable of being clearly distinguished.

In Ceratinella, as here used, the abdomen bears a hardened dorsal
plate, the head of the male is without pits and the claw of the
chelicera has a double curve, first concave and then convex without,
and the embolus is of the spiral type with a very long tailpiece.

**Key to the Males of Ceratinella**

1. Tibial apophysis a short triangular incurved tooth
   - **sphaerica**, Em. p. 10

2. Tibial apophysis long and slender, extending at right angles to the segment

2. Abdomen distinctly hairy
   - **placida**, Banks p. 9

3. Abdomen not so hairy
   - **brunnea**, Em. p. 7

---

**Ceratinella brunnea** Emerton

Plate 1, figure 1

Conn. Acad. Trans. 6:36, pl. 8, fig. 3. 1882

Ceraticelus brunneus Simon. Ar. Fr. 6:596. 1884


Ceratinella brunnea Barrows. Ohio Jour. Sci. 18:302. 1918


**Male.** Length, 1.5 - 1.6 mm. Cephalothorax dark russet brown; viewed from above, rather broad, rounded on the sides, the outline
slightly constricted at the cervical groove, squarely rounded in front.
Viewed from the side, the outline ascends evenly and rather steeply
and is rounded over the head. Head normal, without lobes. Cly-
peus straight and nearly vertical. Posterior eyes in a slightly proc-
curved line, nearly equal and separated by the diameter. Anterior
eyes in a straight line, the median smaller than the lateral, separated
by the radius of the median.

Sternum and labium dusky over a yellowish brown ground color, endites less dusky. Chelicerae yellowish brown, lighter distally; claw with a double curve. Legs yellowish orange, patellae lighter.
Dorsal sclerite of abdomen well developed, distinct, covering nearly the whole surface, nearly black with a large reddish brown area in the middle suffused with blackish. Epigastric sclerite yellowish brown, the posterior lateral angles produced backward and rounded. Infra-mammary sclerite distinct. Soft parts dark greenish gray in alcohol.

Tibial process of palpus long, gently curved and hooked at tip and extending laterally nearly perpendicular to the segment. When the palpus is in its normal position the tibial process projects forward and gives the spider a characteristic appearance by which it can be readily distinguished from related species. The paracymbium is rather slender, strongly but regularly curved and slightly hooked at tip. The embolic division consists of a spiral band which lies across the groove of the tegulum. Basally it is produced into a twisted tail-piece and apically it becomes cylindrical and slender. At the point where the ejaculatory duct unites with the hard part of the embolus there is a sharp bend so that the apical part of the embolus lies parallel to the preceding part and the tip rests between the middle turn of the spiral and the bezel (figure 1).

**Female.** Length, 1.8–2 mm. Resembles the male in color. Dorsal sclerite of abdomen smaller than in the male and very dark brown suffused with blackish. The middle lobe of the epigynum is a smooth convex heart-shaped plate broadest in front.

We examined the type C. occidentalis Banks, a female, in the Museum of Comparative Zoology and compared it with New York specimens of C. brunnea. They appear to be the same species. The epigyna are alike. The type specimen has the abdomen fully distended and it looks smoother and the general coloration is lighter but we have specimens from Missouri that are as light.

**Type Localities.** Mount Washington, N. H.; Salem, Mass.; Saugus, Mass.; New Haven, Conn.

New York: Mount McIntyre, Essex county, 4000 ft., July 1, 1923, 1♀; Uphill brook and Opalescent river, Essex county, July 1918, 1♂ 1♀; Mount Whiteface, Essex county, August 22, 1916, 1♂; Wilmington Notch, Essex county, August 21, 1916, 1♂ 1♀; Raquette Falls, Franklin county, Aug. 24, 1922, 1♀; Gilman lake, Hamilton county, April 27, 1923, 1♂ 1♀; Lake Pleasant, April 27, 1923, 2♂ 4♀; Barneveld, 1919, 1♀; Howland’s island, Wayne county, Nov. 13, 1915, 1♀; Olcott, Mar. 23, 1924 (Dietrich); Penn Yan, May 4, 1922, 1♂; Interlaken, July 1904, 1♀; Enfield Glen, Tompkins county, Oct. 10, 1920, 1♂ 1♀; Danby, Oct. 18, 1924, 2♂ 1♀; Ithaca, May, 1♀; July, 1♀; April 6, 1919, 1♀; Oct. 10, 1924, 2♀; Freeville, Oct. 12, 1924, 1♀; Juanita island, Lake George, Aug. 2, 1920, 1♀; Slide mountain, Ulster county, Aug. 9, 1923, 1♀; Maratanza Lake, Ulster county, 2223 ft., May 24, 1920, 1♀; Oakland Valley, May 26, 1920, 2♀.

Pennsylvania: Loganton, Aug. 1911, 1♂ 1♀.

Virginia: Falls Church, 2♀ (Banks).

Minnesota: Lake Minnetonka, Aug. 8, 1924, 1 ♀ (Fletcher).
Oklahoma: Newkirk, Oct. 28, 1907, 1 ♀.
New Mexico: Beulah, 8,000 ft., March, 2 ♀. (Type of C. occidentalis Banks).
The species has also been recorded by Emerton from Labrador: Battle Harbor; Ontario: Ottawa; Massachusetts: Readville; by Banks from North Carolina: Black Mountains; by Barrows from Ohio: Columbus.

**Ceratinella placida** Banks

Plate 1, figures 2–3

*Ceratinella placida* Banks, Phila. Acad. Nat. Sci. Proc. 1892, p. 32, pl. 2, fig. 54, 54a
*Ceratinella placida* Banks, Phila. Acad. Nat. Sci. Proc. 1916, p. 72, pl. 10, figs. 6, 11

**Male.** Length, 1.5 mm. Cephalothorax brownish orange-yellow, rather broad; viewed from above, rounded on the sides behind, convergent towards the front without constriction at the cervical groove, broadly rounded in front; viewed from the side, gently arched and gradually ascending to just back of the posterior eyes. Clypeus concave, slightly protruding. Posterior eyes in a gently procurved line, the median separated from each other by a little less than the diameter, closer to the lateral. Anterior eyes in a straight line, the median as large as the lateral, separated from each other by less than the radius and from the lateral by the radius.

Sternum yellow-orange, margin narrowly blackish. Labium the same, darker at tip. Endites lighter than sternum. Claw of the chelicera with a double curve. Legs orange-yellow, lighter distally, patellae pale. Dorsal abdominal sclerite large, orange-yellow, distinctly hairy. Epigastric sclerite with a squarish area of soft integument in front of the genital opening, the lateral angles produced a considerable distance posteriorly, straight on the inside, rounded without. Inframammillary sclerite very broad, not surrounding the spinnerets. Soft parts of abdomen grayish, distinctly hairy.

Femur of palpus nearly straight, cylindrical. Patella short, as thick as femur. Ratio of length of femur to that of patella as 13 to 6. Tibia as long as patella, armed with a long, gently curved, blackish dorso-lateral apophysis which has a small, sharp, incurved hook at tip (figure 3). The apophysis extends at a right angle to the tibia. Paracymbium rather broad at base, strongly curved. Bezel rather low, margin sinuate, the posterior angle upturned. Tailpiece of the embolic division broad at base, abruptly narrowed, long and slender, the tip turned outward over the edge of the cymbium. On emerging from the bezel the embolus is broad and flat, slightly grooved; it makes a semicircular spiral curve and this is
bent on itself so that the slender apical part lies nearly parallel with the basal part. The tip lies at the edge of the bezel (figure 2).

**Female.** Length, 1.6 mm. Similar to the male in form and color. The dorsal abdominal sclerite is relatively smaller. The epigynum is practically the same as that of *C. brunnea*.

This species is very closely related to *C. brunnea*. It is generally lighter in color. The abdomen and legs are much more hairy. In the male the anterior median eyes are apparently larger, almost as large as the anterior lateral and the clypeus is wider than in *C. brunnea*. In the female the clypeus is the same in both species. We are unable to find any differences in the palpi.

**Type locality.** Ithaca, N. Y. 1♂ (Banks).

District of Columbia: Washington, 1♂ (Chamberlin).

Virginia: Falls Church, 2♀ (Banks).

Missouri: Columbia, Nov. 23, 1904, 1♂ (under stone); May, 1♀; Oct., 1♀.

*Ceratinella sphaerica* Emerton

Plate 1, figures 4–6; plate 2, figure 7; plate 12, figure 114

Conn. Acad. Sci. 16:388, pl. 1, fig. 4, 1911

**Male.** Length, 1.5 mm (figures 5–7). Cephalothorax smooth, dark brownish yellow, with indistinct radiating blackish markings; viewed from above, broad, rounded on the sides, strongly convergent towards the front, bluntly rounded in front; viewed from the side, moderately steep and gently arched over the back to the head and then more strongly arched over the head. Clypeus nearly vertical, convex below the anterior median eyes and then straight. Posterior eyes in a gently procurred line, separated from each other by a little more than the diameter. Anterior eyes in a straight line, the median smaller than the lateral, separated from each other by the radius and from the lateral by the diameter.

Sternum broad, smooth and shining, dark grayish brown. Endites the same but lighter. Chelicerae yellowish. Coxae grayish brown, lighter than the sternum. Trochanters grayish. Distal margin of coxae and proximal margin of femora narrowly ringed with black. Legs and palpi orange-yellow. Abdomen projects over the thorax farther than usual. The dorsal sclerite large and heavy, extending over the front end of the abdomen, reddish brown, smooth but densely and finely sculptured. Epigastric sclerite not well developed, weakly chitinized and indistinct in front, a large area of soft integument between epigastric plates; posterior lateral angles rather indistinct. Inframammillary sclerite broad confined to the ventral side of the spinnerets. Soft parts of the abdomen dark gray with irregular lighter areas.

Femur of palpus gradually thicker towards tip. Patella as thick as femur. Ratio of length of femur to that of patella as 14 to 7. Tibia as long as patella dorsally, the dorso-lateral apophysis has the form of a triangular incurved tooth. Cymbium with a single groove at the lateral margin. Paracymbium broad at base, strongly curved in a semicircle. Bezel with the proximal angle black, round-pointed, the upper edge sinuate with a notch where the apical part of the
embolus emerges. Tailpiece of the embolus broad, spirally curved, the tip curved outward. The apical part of the embolus on emerging from the bezel is broad and grooved, black on the sides and pale in the middle. It makes a spiral curve to the tip of the cymbium where it is joined by the ejaculatory duct and then curves up over and back down so that the tip lies near the bezel. The duct does not become free (figures 4, 6).


**SPECIES PLACED BY BANKS IN CERATINELLA AND BELONGING ELSEWHERE**

_Ceratinella annulipes_ Banks (Phila. Acad. Nat. Sci. Proc. 1892, p. 33) is the _Lophocarenium latum_ Emerton. We have compared the types.

_Ceratinella moesta_ Banks (Phila. Acad. Nat. Sci. Proc. 1892, p. 32) is a true Lophocarenium.

**Ceraticelus Simon**

_Arachnides de France, 5:595. 1884_

The status of this genus is fully discussed under Ceratinella (p. 56). It differs from that genus in having the claw of the chelicera with but a single curve.

**Key to the Males of Ceraticelus**

1. Head divided into two lobes ................................................................. 2
2. Head not divided ................................................................................. 7
3. The two cephalic lobes touching, leaving a rounded concavity between them ................................................................. 3
4. The two cephalic lobes divergent, not touching ....................................
5. Lateral eyes on a distinct rounded hump .................. _bulbosa_ Emerton p. 16
6. Lateral eyes not on a distinct rounded hump ........................................
7. Patella of palpus with a row of four or five long, curved hairs on the dorso-mesal aspect .................................................. _alticeps_ Fox p. 13
8. Patella of palpus without such a row of hairs ........................................
9. The cephalic lobes separated by a straight transverse suture. Abdomen very dark .................................................. _atriceps_ Cambridge p. 15
10. The anterior cephalic lobe hollowed out above along the suture so that the posterior lobe rests in the concavity. Abdomen lighter ................................................................. _passalis_ n. sp. p. 40
11. Anterior cephalic lobe not extending so far in front of the posterior lobe and much lower. Tibial apophysis without the scooplilke structure .................................................. _paludigena_ n. sp. p. 39
12. Anterior cephalic lobe extending far in front of the posterior lobe and as high as the latter. Tibial apophysis provided with a semitransparent scooplilke structure .................................................. _fissiceps_ Cambridge p. 22
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Key</th>
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<tbody>
<tr>
<td>7</td>
<td>Eye region broadly concave.</td>
<td>\textit{laticeps} Emerton p. 30</td>
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<tr>
<td></td>
<td>Eye region not concave.</td>
<td></td>
</tr>
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<td>8</td>
<td>Head produced forward into a single rounded lobe.</td>
<td></td>
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<tr>
<td></td>
<td>Head normal.</td>
<td></td>
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<tr>
<td>9</td>
<td>Apical part of embolus with a long lateral branch.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Apical part of embolus without a lateral branch, sometimes with a short tooth</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Lateral branch of apical part of embolus bifid at tip</td>
<td>\textit{creolus} Chamberlin p. 19</td>
</tr>
<tr>
<td></td>
<td>Lateral branch of apical part of embolus simple at tip, not bifid</td>
<td>\textit{emertoni} Cambridge p. 20</td>
</tr>
<tr>
<td>11</td>
<td>Back of cymbium strongly angulate.</td>
<td>\textit{pygmaeus} Emerton p. 41</td>
</tr>
<tr>
<td></td>
<td>Back of cymbium rounded, not angulate.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Tibial apophysis obliquely truncate at tip.</td>
<td>\textit{similis} Banks p. 42</td>
</tr>
<tr>
<td></td>
<td>Tibial apophysis with a large tooth on the outside near the base, narrow and sharp-pointed at tip.</td>
<td>\textit{limnologicus} n. sp. p. 32</td>
</tr>
<tr>
<td>13</td>
<td>Tibial apophysis long.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tibial apophysis short.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Back of cymbium strongly angulate.</td>
<td>\textit{fasticidiosus} n. sp. p. 22</td>
</tr>
<tr>
<td></td>
<td>Back of cymbium rounded.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Tibial apophysis projecting forward, very long, slender, evenly curved, reaching nearly to end of tarsus.</td>
<td>\textit{tibialis} Fox p. 44</td>
</tr>
<tr>
<td></td>
<td>Tibial apophysis extending at right angle to tibia and bent at a right angle.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Tibial apophysis bent near base.</td>
<td>\textit{nesiotes} Crosby p. 36</td>
</tr>
<tr>
<td></td>
<td>Tibial apophysis bent near tip.</td>
<td>\textit{formosus} Banks p. 25</td>
</tr>
<tr>
<td>17</td>
<td>Posterior lateral angles of epigastric sclerite coalescent behind the furrow.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Posterior lateral angles of epigastric sclerite not coalescent behind the furrow.</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Posterior lateral angles of the epigastric sclerite narrowly united</td>
<td>\textit{minutus} Emerton p. 34</td>
</tr>
<tr>
<td></td>
<td>Posterior lateral angles of the epigastric sclerite broadly united</td>
<td>\textit{micropalpis} Emerton p. 33</td>
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<tr>
<td>19</td>
<td>Tibial apophysis broad and thin, armed on the inner side with a small sharp black tooth and on the truncate tip with three minute teeth.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Length 1 mm.</td>
<td>\textit{titivillium} n. sp. p. 45</td>
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<tr>
<td></td>
<td>Tibial apophysis not of this form. Length 1.5 mm.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Edge of cymbium next to paracymbium with a single groove.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Edge of cymbium next to paracymbium with two grooves separated by a carina.</td>
<td></td>
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<tr>
<td>21</td>
<td>Tip of embolus produced beyond the point where the ejaculatory duct is thrown off.</td>
<td>\textit{laetabilis} Cambridge p. 26</td>
</tr>
<tr>
<td></td>
<td>Tip of embolus simple; the ejaculatory duct not free distally</td>
<td>\textit{ornatulus} n. sp. p. 38</td>
</tr>
<tr>
<td>22</td>
<td>Base of the free part of the ejaculatory duct undulate externally</td>
<td>\textit{laetus} Cambridge, p. 29</td>
</tr>
<tr>
<td></td>
<td>Base of the free part of the ejaculatory duct smooth</td>
<td>\textit{carinatus} Emerton p. 17</td>
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<td>\textit{albus} Fox and \textit{parvulus} Fox are not included in the above key.</td>
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Ceraticelus albus Fox

Plate 2, figures 8 and 9

Erigone (Ceratinella) alba Fox. Ent. Soc. Wash. Proc. 2:44. 1891

The original description is brief and no figure was published. The type is lost except one palpus mounted in balsam. The figures which Crosby published in 1905 were drawn from this specimen (figures 8–9).

Fox states that this species resembles C. fissiceps but is distinguishable by its lighter color and very small palpus. It may be based on recently molted and light-colored individuals of that species. The palpus of the type is flattened in the balsam and is not in good condition for study but a comparison with the palpus of C. fissiceps shows no striking difference of size or form. We would retain it provisionally as a good species hoping that future collecting in the District of Columbia will bring to light specimens that will establish its validity.

In the Museum of Comparative Zoology are several specimens from Coy Glen, Ithaca, N. Y., May 23, determined by Banks as C. albus, but they are recently molted C. fissiceps. We have found many pale specimens of C. fissiceps at that time of year.

Type locality. District of Columbia.

Ceraticelus alticeps Fox

Plate 2, figures 10–14

Erigone (Ceratinella) alticeps Fox. Ent. Soc. Wash. Proc. 2:45. 1891

Male. Length, 1.4 mm. Cephalothorax yellowish orange suffused with dusky, darker along the middle and on the sides. Posterior cephalothoracic lobe and a narrow collar behind it dusky. Black around the anterior median eyes. Cephalothorax viewed from above evenly rounded on the sides and broadly rounded in front (figure 10); viewed from the side the outline is evenly rounded over the back to the posterior cephalothoracic lobe which arises as a rather high hemispherical bump overhanging in front where it touches the anterior lobe but leaving a small round hole completely through the head between the lobes just back of the anterior median eyes (figure 13). Clypeus wide, convex and retreating.

Posterior eyes in a procurved line, the median borne in front of the middle of the lobe. Anterior eyes in a procurved line, the median close together on the front of the anterior lobe and widely separated from the lateral.

Legs pale yellowish orange, the posterior tibiae decidedly dusky; sternum yellow-orange, dusted with dusky, darker at the margin. Endites and chelicerae yellow-orange. Soft parts of abdomen pale
yellowish white. Dorsal abdominal sclerite large, yellow-orange, lighter than the cephalothorax. Epigastric sclerite strongly chitinized, yellow-orange. Mammillary sclerite paler, nearly surrounding the spinnerets. Femur of palpus straight, cylindrical; patella broad, compressed, enlarged distally, thicker than the femur and bearing on inner upper surface a row of four curved black hairs. Length of patella and femur in the ratio of 11 to 17. Tibial apophysis broad at base, bent at the middle at an angle of more than 45 degrees and armed on the inside with a strong tooth (figure 11).

Cymbium strongly angulate and with a ridge over the back armed with a row of stiff curved hairs. Paracymbium long and slender, curved at the tip, of the general type of C. fissiceps. Between the paracymbium and the cymbium a delicate membrane is to be seen. The embolic division of the bulb is of the C. fissiceps type, the ejaculatory duct leaves the embolus some distance before the tip and after making a small loop the end lies within the enlarged edge of the tegulum protected by a membranous conductor (figures 11–12).

In male specimens from the summit of Mount Mitchell, N. C., the posterior cephalic lobe is higher and wider behind the eyes. These males are a little larger.

Female. Length, 1.4 mm. Similar to the male in coloration. Cephalothorax dark orange, head black, the black extending back to the dorsal groove. Head normal, not elevated. Abdomen provided with a distinct orange dorsal sclerite.

Epigynum with the middle lobe similar to that of C. fissiceps. The confining ridges are bent inward behind like a hook (figure 14).

Fox's specimens are lost with the exception of one palpus mounted in balsam. We have compared this with the specimens from Riverhead and they agree in detail.

Type locality. District of Columbia.

New York: Long pond, Suffolk county, June 29, 1924, 2♂; Cold Spring Harbor, July 4, 1907, 2♂ 1♀; Aug. 7, 1907, 1♂; Aug. 10, 1907, 1♂ 1♀ (Bryant); Aug. 10, 1905, 1♂ 1♀ (Bryant); Riverhead, beach of Long Island sound, Sept. 10, 1922, 1♂; collected on the sand at the high water line under the shade of succulent plants, April 11, 1924, 1♂; Baiting Hollow, Suffolk county, May 23, 1924, 1♂ 8♀; April 8, 1924, 1♂ 1♀; May 31, 1923, 3♂ 6♀.

Massachusetts: Duxbury, April 1, 1913, 2♂ 1♀ (Clapp); Woods Hole, July 1919, 1♀ (Forbes).

District of Columbia: April, 3♂ (Fox); Washington 1♂ 5♀ (Banks).

Virginia: Alberta, Oct. 27, 1923, 2♂ 7♀; Falls Church 5♀ (Banks).


Remarks. This species is sometimes found on the sand along the sea beach but is more often taken in sifting in rather dry woods.
Ceraticelus atriceps Cambridge

Plate 2, figures 15 and 16; plate 3, figures 17 and 18


Ceratinella atriceps Emerton, Conn. Acad. Sci. Trans. 6:34, pl. 7, fig. 5. 1882

Ceraticelus atriceps Simon. Ar. Fr. 5:596. 1884

Ceratinella atriceps Banks. Phila. Acad. Nat. Sci. Proc. 1892, p. 32 (This refers to Exechophysis plumalis Crosby)


Ceratinella atriceps Banks, Phila. Acad. Nat. Sci. Proc. 1916, p. 71 (This refers to Exechophysis plumalis Crosby)


Male. Length, 1.5 mm. Cephalothorax yellow-orange, dark in the middle, along the sides and around the eyes. Posterior cephalic lobe blackish. Viewed from above, the cephalothorax is evenly rounded on the sides and pointedly rounded in front, slightly constricted opposite the anterior median eyes; viewed from the side, the outline is evenly arched over the back to the base of the posterior cephalic lobe (figure 16). The latter, seen from the side, is a rather low hump rounded in front and behind and slightly flattened above. The posterior median eyes are borne on the sides in front of the middle. The posterior lobe partly overhangs the anterior lobe which it touches, leaving a hole through the head. Clypeus, wide, convex above, concave and retreating below.

Posterior eyes in a recurved line; anterior eyes also recurved, the median close together on the anterior lobe and widely separated from the lateral. Sternum yellow, suffused with dusky, much darker at the margin; labium dusky; endites and chelicerae yellow, only slightly dusky. Legs and palpus pale yellowish.

Abdomen nearly black, in alcohol sometimes greenish. The dorsal sclerite is often absent or indistinct. When present it is orange, more or less suffused with blackish. The epigastric sclerite well developed, dark brown, with a small angular projection back of the furrow on each side. Infrafrontal scalyerite variable in development, sometimes indistinct.

Palpus closely resembles that of C. fissa ce ps but tibial process relatively shorter, and darker at the end. Length of patella and femur in the ratio of 14 to 17. The embolic division is of the fissiceps type (figures 17-18).

Female. Length, 1.6 mm. Resembles the male in color. Cephalothorax yellowish orange, grayish at the sides and sometimes in the middle, eyes in a blackish area which extends backwards from the eyes about half way to the dorsal groove. At least the lower half of clypeus orange. Abdomen without dorsal sclerite; ventral sclerites same as in male. The ducts leading to the spermathecae
open on the face of the epigynum and each opening is guarded by a thickened ridge in front and on the side. The duct is chitinized, dark brown and shows clearly through the integument just in front of the opening of the duct. The spermathecae are evident but not so prominent as the ducts. The middle lobe is square behind and pointed in front between the ridges mentioned above (figure 15).

Type locality. Cambridge, Mass.

New York: Mount Whiteface, Essex county, Aug. 24, 1921, many ♂ and ♀; Mount McIntyre, Essex county, July 1, 1923, many ♂ and ♀; Uphill brook and Òpalescent river, July 1, 1918, 1 ♂ 4 ♀; Wilmington Notch, Essex county, Aug. 21, 1916, 1 ♂; Mount Marcy, 3400 ft., Sept. 3, 1922, many ♂ and ♀; Lake Tear, Mount Marcy, 4500 ft., July 1918, 2 ♂; Sept. 4, 1922 several; Chapel pond, Essex county, June 28, 1923, 1 ♂; Mountain Lake, Fulton county, April 26, 1923, 6 ♀; Wells, April 27, 1923, 1 ♂; Bumps pond, Washington county, July 28, 1920, 1 ♂; Lake Keuka, Dec. 1905, 2 ♀; McLean, May 30, 1919, 2 ♀; Oct. 18, 1919, 4 ♀ 3 ♂; April 24, 1924, 2 ♀; Ithaca, April 6, 1919, 1 ♀; Oct. 18, 1902, 1 ♀; Mar., 1 ♀, Coy Glen near Ithaca, Oct. 4, 1912, 1 ♀; Enfield Glen, Tompkins county, Oct. 12, 1924, 2 ♀; Jenksville, Oct. 27, 1924, 1 ♀; Little pond, Orange county, May 25, 1920, many ♂ and ♀; Oakland Valley, May 26, 1920, 1 ♂.

New Hampshire: Intervale, 20° 19' July-Aug. 1915, 1 ♂; Moosilauke, July 8, 1912, many ♂ and ♀.


In the Cornell University collection is a male of atriceps determined by Banks as bulbosa and recorded as such in Phila. Acad. Nat. Sci. Proc. 1892, p. 32.

Emerton also records the species from Quebec: Lake Megantic; British Columbia: Field.

Remarks. While this species is sometimes taken in sifting, it can be obtained in greater abundance by beating hemlocks and other conifers.

**Ceraticelus bulbosus** Emerton

Plate 3, figures 19–23; plate 12, figure 110

_Ceratinella bulbosa_ Emerton. Conn. Acad. Sci. Trans. 6:33, pl. 7, fig. 3. 1882


_Ceraticelus bulbosus_ Simon. Ar. Fr. 5:596. 1884


**Male.** Length 1.35 mm. Cephalothorax elevated in front and the head divided into two squarish lobes by a transverse furrow. The posterior lobe seen from the side is perpendicularly elevated behind and rounded above, the top nearly flat (figure 22). Seen from above, narrower in front than behind (figure 23). The posterior median eyes borne well forward. The anterior lobe protrudes
prominently and bears the anterior median eyes on the upper anterior face. Seen from above evenly rounded in front with the sides slightly constricted just in front of the lateral eyes. Lateral eyes on each side borne on a low, common tubercle. The cephalic lobes and the lateral eye tubercle nearly black; the black not extending back of the lobes. Cephalothorax yellowish orange. Sternum orange, dusky on the margin. Legs and palpus (except tarsus) yellowish. Dorsal sclerite of abdomen distinct, yellowish orange, soft parts grayish orange. Epigastric sclerite orange with the posterior lateral angles slightly more rounded than in fissiceps. Inframamillary sclerite distinct but confined to ventral surface. Tibial process of palpus shorter and more strongly curved than in fissiceps and has the lateral tooth longer and sharper. Back of tarsus not angulate or carinate. Ratio of length of femur to that of patella 17 to 10. Paracymbium slender, curved at tip. Between the paracymbium and the edge of the cymbium there projects a membraneous lobe (figure 20). Embolic division of the bulb has a rather long, flat, curved tailpiece. Where the embolus emerges from the bezel it is grooved and bears a short pointed branch on the side (figure 19). The ejaculatory duct leaves the embolus before the tip and curves back towards the bezel but is not looped. Female. Length, 1.5 mm. Resembles the male in color. Head black, the colored area not so clearly defined as in the male. Abdomen yellowish orange, coriaceous but without a distinct dorsal sclerite. Middle lobe of epigynum nearly square, the lateral confining ridges semi-circular, evident only on the sides (figure 21). Described from 1♂ and 2♀ specimens from McLean, N. Y. Type locality. New Haven, Conn. New York: McLean, May 14, 1919, 1♂ 2♀; May 30, 1♂ 1♀; June 21, 1924. Collected by sifting moss in a bog. Banks' records (1892) are probably erroneous. The specimens he left at Ithaca were all atriceps, which is common in the places mentioned. Remarks. We have found this rare species only by sifting in a cold sphagnum bog.

**Ceraticelus carinatus** Emerton

*Plate 3, figures 24–26*

*Ceratinella carinata* Emerton. Conn. Acad. Sci. Trans. 16:388, pl. 1, fig. 5. 1911

**Male.** Length, 1.5 mm. Cephalothorax dark reddish brown, finely but sharply reticulate; viewed from above, rounded on the sides, narrowed towards the front, slightly constricted at the cervical groove and rounded in front; viewed from the side, evenly arched over the back to the head and then rounded down to the posterior eyes. The head is higher behind the eyes than in laetabilis, Clypeus straight and nearly vertical.
Posterior eyes in a gently procurved line, separated from each other by the diameter. Anterior eyes in a recurved line, the median almost touching and separated from the lateral by the diameter. Sternum and labium reddish brown, the former coarsely reticulate as in *laetabilis*. Endites light orange-yellow. Hind coxae separated by a little more than the length. Legs and palpi light orange-yellow.

Dorsal abdominal sclerite orange-yellow. Epigastric sclerite with the insertion of the pedicel at the center, posterior lateral angles projecting only a short distance, rounded; lateral ridges strongly developed. Inframamillary sclerite confined to ventral side. Soft parts of abdomen grayish white.

Femur of palpus gradually enlarged below towards tip, almost protuberant near the end. Patella short, strongly curved ventrally. Ratio of length of femur to that of patella as 19 to 7. Tibia shorter than in *laetabilis* and the dorso-lateral apophysis is not so large but the edge is finely serrate. Cymbium with two deep curved grooves at the lateral margin as in *laetus* (figure 24). Paracymbium as in *laetus*. Tailpiece of the embolic division slender, long, strongly curved, pointed at tip. Apical part of the embolus as in *laetus*, but the free part of the ejaculatory duct without the semi-transparent lobes at the base (figure 25).

The above description taken from a specimen from Sudbury, Mass. In specimens from North Carolina the coloration is brighter. The soft parts of the abdomen are greenish gray with small irregular light spots.

**Female.** Length, 1.7 mm. Similar to the male in form and color. Abdomen without a dorsal sclerite. In recently moulted specimens the abdomen is nearly white; in older specimens it is gray with a distinct pattern, light across the front and in a broad longitudinal stripe which is crossed by four or five transverse bars. All gradations in depth of coloring are found. Epigastric sclerite divided into three parts by longitudinal sutures, lateral ridges strongly developed. Inframamillary sclerite, broad, only half way surrounding the spinnerets. Epigynum similar to that of *laetus* but the anterior triangular part of the middle lobe is not so deeply notched (figure 26). The transverse ridge in front of the epigynum not so large as in *laetabilis*.

Female described from specimens from Grandfather mountain, N. C.

**Type localities.** Springfield, Sudbury and Concord, Mass.
Massachusetts: Sudbury Oct. 1, 1905, 1♂ (Emerton).

**Remarks.** This species has been taken by sifting in moderately dry woods.
Ceraticelus creolus Chamberlin n. sp.

Plate 4, figures 27-31

**Male.** Length, 1.5 mm. Cephalothorax reddish orange-yellow, rather long; viewed from above, evenly rounded on the sides behind, the sides evenly convergent towards the front, rounded in front (figure 30). Viewed from the side, rather steeply ascending behind and then more gradually to the top of the head behind the eyes with a broad depression at the cervical groove, rounded in the eye region. Head rather high and projecting forward (figure 29). Clypeus high, broadly convex above and concave below, strongly retreating. Posterior eyes in a recurved line, the median separated from each other by nearly twice the diameter and from the lateral by a little more than the diameter. Anterior eyes in a straight line, the median smaller than the lateral, separated from each other by less than the radius and from the lateral by nearly twice the diameter.

Sternum orange-yellow, lightly dusted with grayish, darker at the margin. Labium darker, endites lighter. Hind coxae separated by the length. Legs and palpi light yellowish.

Dorsal abdominal sclerite rather small, orange, minutely roughened, more distinctly so in front. Epigastric sclerite orange-yellow, rather small but outline distinct, smooth without lateral ridges, posterior lateral angles short, rounded. Inframammillary sclerite broad, not extending above the spinnerets. Soft parts of abdomen pale yellow, clothed with small hairs arising from inconspicuous tubercles.

Femur of palpus nearly cylindrical and nearly straight; patella thicker than the femur strongly curved at base. Ratio of length of femur to that of patella as 14 to 9. Tibia short with a very large dorso-lateral apophysis, the latter broad and flat on basal part with a very small lateral tooth, the distal part slender and bent at a right angle to the basal part (figure 28). Paracymbium rather stout, moderately curved, slightly hooked at tip. Tailpiece of embolic division very long, nearly straight, notched on the inside at base, the tip turned outward. On emerging from the edge of the bezel the apical part of the embolus is very stout. It soon throws off, on the outside, a very long slender branch which is bifid at tip (figure 27). It then makes a short curve and ends in a short groove and twisted point just back of which the free part of the ejaculatory duct is thrown off. The latter makes two spiral turns and the tip lies inside the bezel. The second turn is high above the surface of the bulb.

**Female.** Length, 1.4 mm. Similar to the male in general form and color. The head is not so high nor produced forward. The eyes are closer together, the posterior median being separated by a little less than the diameter. Abdomen without a dorsal sclerite. Epigastric sclerite without lateral ridges, divided by sutures into three parts. Inframammillary sclerite broad, not surrounding the spinnerets. Soft parts of abdomen pale yellowish.
Middle lobe of epigynum consists of two parts; the posterior part is a short transverse plate, the anterior part is inverted heart-shaped and overlaps the former (figure 31). The openings on the sides are bounded on the inside by parallel, longitudinal ridges and covered in front by rounded lateral lobes. The ducts of the spermathecae form an acute angle with the longitudinal ridges. Epigastric plate transversely wrinkled in front of the epigynum.

Described from a paratype from Benton, La.
Virginia: Alexandria, 1♂ (Chamberlin); Alberta, Oct. 27, 1923, 1♂ 1♀.
District of Columbia: Washington, 1♂ (Banks).
Louisiana: Benton, 1♂ 1♀ (Chamberlin). Paratypes of C. creolus.

Ceraticelus creolus is included in this revision through the courtesy of Dr R. V. Chamberlin of the Museum of Comparative Zoology, Cambridge, Mass., who described the species.

Ceraticelus emertoni Cambridge
Plate 4, figures 32–36; plate 12, figure 112

Ceratinella emertoni Emerton. Conn. Acad. Sci. Trans. 6:32, pl. 7, fig. 1. 1882
Ceraticelus emertoni Simon. Ar. Fr. 5:596. 1884
Erigone emertoni Keyserling. Spinnen Amerikas, Theridiidae, 2:178, pl. 17, fig. 237. 1886
Ceratinella emertoni Barrows. Ohio Jour. Sci. 18:302. 1918

Male. Length, 1.5 mm. The cephalothorax orange-yellow narrowly margined with dusky; a blackish area surrounds the eyes but usually does not extend back to the cervical groove (figure 36). The head is elevated, projects forward and is bluntly rounded in front, not divided into lobes as in fissiceps (figure 35). The clypeus is slightly convex above and broadly concave below. Posterior eyes in a slightly recurved line, the median separated from the lateral by the diameter and from each other by a little greater distance.

The legs and palpus pale yellowish. Sternum yellowish dusky on the margin. Abdomen with a distinct dorsal sclerite, orange-yellow, soft parts pale yellow. Epigastric sclerite distinct, orange-yellow, tickier and darker along the furrow. Inframammillary sclerite distinct, paler than the epigastric.

Tibial process of the palpus broad at the base with a broad tooth on outside and a smaller tooth on the inside; the apex is slender, curved, sharp-pointed and black (figure 33).
The embolic division consists of a rather short and thick tailpiece which is twisted and turned almost at a right angle at the downward curve of the spiral. The embolus emerges from the edge of the bezel as a broad, black, flattened rod which throws off a slender curved branch on the outside of the curve (figure 32). The embolus is constricted and bent at the point where the ejaculatory duct leaves it; the tip slender, bluntly rounded at the end. The free part of the ejaculatory duct coiled in one and one-half turns.

**Female.** Length, 1.4 to 1.5 mm. Resembles the male in color; head not elevated; black area surrounding the eyes not extending much behind the eyes. Abdomen without dorsal sclerite, pale yellow. The epigynum has the middle lobe narrowed in front and rounded on the sides, (figure 34). The openings are placed at the side of the middle lobe and are guarded by chitinized ridges, thickest and darkest on the inner side. The ducts of the spermathecae are nearly black and show distinctly. The middle lobe has the lateral margin nearly black and has a triangular dark mark behind.

**Type locality.** Amesbury, Mass.

New York: Lake Tear, Essex county, 4300 ft. July 11, 1918, 1 ♀; Black brook, Clinton county, June 11, 1916, 1♂; Barneveld, 1919, 1♂; July 22, 1919, 1♀; Aug. 11, 1919, 2♀; Aug. 18, 1919, 1♀; Sept. 13, 1919, 1♀; Sacandaga Park, June 3, 1♀ (Alexander); Point Breeze, Orleans county, June 11, 1922, 2♂ 2♀; Letchworth Park, July 9, 1922, 4♀; Geneva, Nov. 14, 1914, 1♀; Lake Keuka, Oct. 1903, 1♀; Honeoye Falls, July 1912; Horseheads, Apr. 1904, 1♀; Ithaca, May, 1♀, June, 1♀; July, 1♂; July, 2♀; May, 1♂ 1♀; Mar., 1♀; Oct., 7♀; Nov. 1, 1902, 2♂ 2♀; Aug. 1904, 1♀; Aug. 4, 1909, 1♂ 2♀; Oct. 4, 1912, 1♀; May 21, 1920, 1♀; Ringwood, Tompkins county, May 20, 1919, 1♀; Coxsackie, Mar. 11, 1925, 1♂; Canastota, Nov. 1, 1922, 2♀; McLean, Sept. 28, 1912, 1♀; Cold Spring Harbor, July 6, 1907, 6♂ 8♀; July 13, 1907, 16♀; July 10, 1907, 2♂ 20♀; July 23, 1907, 1♂ 7♀; Aug. 8, 1907, 11♂ 20♀; Aug. 9, 1907, 5♂ 15♀; Aug. 10, 1907, 1♀; Aug. 15, 1907, 6♂ 12♀; Aug. 7, 1907, 3♂ 3♀; Aug. 17, 1907, 14♀; Summer 1907, 1♂ 5♀ (Bryant); Oyster Bay, 4♂ (Chamberlin).

New Hampshire: Intervale, Aug. 14, 1914, 1♀; July 17, 1913, 3♀; Moosilauke, July 3, 1912, 1♂.

Massachusetts: Beverley, July, 1904, 1♀; Duxbury, Aug. 1916, 4♂ 10♀ (Bryant).

Connecticut: Amston, June 24, 1918, 1♂ (Bryant); New Haven (Emerton).

Maine: Dexter (Emerton).

New Jersey: Morristown, July 1903, 1♀.

Virginia: Falls Church, 4♀ (Banks).

Ohio: Columbus, May 24, 1916, 1♂ 2♀ (Barrows).

Missouri: Columbia, May, 2♂ 10♀; June, 1♂ 1♀; Oct., 1♀.

The species has also been recorded by Emerton from Massachusetts: Readville; by Barrows from Ohio: Columbus.
**Ceraticelus fastidiosus** n. sp.

Plate 4, figures 37-38

Male. Length, 1.5 mm. Cephalothorax orange diffused with dusky, darker on the head and along the margin, with an irregular black longitudinal stripe on the dorsal furrow; viewed from above, evenly rounded on the sides and in front; viewed from the side, steeply rounded over the posterior declivity and then gradually ascending to the posterior eyes; clypeus vertical, gently concave (figure 37). Posterior eyes in a straight line, equal and equidistant, separated by a little less the diameter. Anterior eyes in gently recurved line, the median smaller than the lateral, subcontiguous and separated from the lateral by the diameter.

Sternum orange, dusky on the margin, labium and endites lighter; legs and palpi yellowish; tibiae of posterior legs blackish.

Abdomen provided with a large orange dorsal sclerite, epigastric and inframammillary sclerite orange. Soft parts of abdomen pale yellow.

Femur of palpus cylindrical, slightly curved towards the tip, patella compressed, widened from the base to the middle. Length of femur and that of the patella in the ratio of 20 to 15. Tibia short and provided with a long, strongly curved apophysis bearing a large lateral tooth. Back of cymbium strongly angulate and with a ridge armed with a row of curved hairs.

Paracymbium long and slender and hooked at the tip. Bezel large, pointed towards the tip of the palpus. Tailpiece of the embolic division long, gently curved and pointed at tip; on emerging from the edge of the bezel, the terminal part is rather stout, grooved and carinate, the outer ridge terminates in a pointed tooth; beyond the tooth it is grooved and twisted and terminates in a sharp point, the duct becomes free a short distance before the tip and is spirally coiled a little more than one turn (figure 38).

Holotype male.

North Carolina: Oteen, Oct. 16, 1923. 1♂

**Ceraticelus fissiceps** Cambridge

(Plate 5, figures 39-43; plate 12, figure 111)

*Erigone fissiceps* Cambridge. Zool. Soc. London Proc. 1874, p. 438, pl. 55, fig. 8
*Ceratinella fissiceps* Emerton. Conn. Acad. Sci. Trans. 6:33, pl. 7, fig. 2. 1882
*Ceraticelus fissiceps* Simon. Ar. Fr. 5:596. 1884
*Erigone fissiceps* Keyserling, Spinnen Amerikas, Theridiidae, 2:155, pl. 16, fig. 221. 1886
*Ceratinella fissiceps* Emerton, Common Spiders, p. 152, figs. 371-73. 1902

Ceratinella fissiceps Barrows. Ohio Jour. Sci. 18:302. 1918,


Ceratinella fissiceps Emerton. Can. Ent. 56:123. 1924

**Male.** Length, 1.5 mm. Cephalothorax elevated in front and divided by an oblique furrow into two lobes bearing respectively the posterior median and anterior median eyes. The posterior lobe seen from the side is gradually elevated behind and rounded in front (figure 41); seen from above, the front of the lobe is evenly rounded (figure 42). The posterior median eyes are borne near the front of the lobe and are separated from each other by twice the diameter. The anterior lobe projects a considerable distance in front of the other lobe and bears the anterior median eyes on the front, which is evenly rounded. The clypeus is strongly retreating. The lateral eyes of each row are contiguous and borne on a more or less pronounced hump. Cephalothorax orange-yellow, the cephalic lobes blackish with black rings around the eyes. The blackish area extends back two-thirds the length of the cephalothorax. Legs and palpus yellowish, paler than the cephalothorax; tibiae and metatarsi, particularly the former, often darkened, sometimes nearly black. Sternum yellowish black on the margin. Abdomen provided with a light orange-yellow dorsal sclerite; soft parts pale yellow. Epigastric sclerite pale orange-yellow, the lateral angles rounded behind. Inframamillary sclerite distinct, paler than the epigastric.

Femur of palpus slender, gently curved towards apex; patella long, slightly compressed, gradually enlarged from base to apex; ratio of length of femur to that of patella as 21 to 17; tibia short, provided with a blunt tooth below and with a long, slender, curved process above that extends to the angle on the back of the cymbium. On the inner edge of the process a small but distinct tooth usually present. The back of the cymbium angulate and compressed into a sharp longitudinal ridge; beyond the angle, the apex of the ridge bears a comblike series of curved hairs (figure 39). Bezel large, pointed towards the tip of the palpus, roughened except on the proximolateral surface where it is slightly concave and smooth. Condutor a conspicuous white membraneous lobe lying just inside the tip of the bezel. Embolic division consists of long, curved, light brown tailpiece and a more slender, black apical part. The tip is obliquely pointed. The ejaculatory duct leaves the embolus before the tip, makes a small loop and the tip rests close to the conductor (figure 40).

**Female.** Length, 1.5 mm. Resembles the male in color, the blackish area on head darker and extends back to the middle of the cephalothorax. Dorsal sclerite of abdomen smaller than in male. Middle lobe of epigynum short and broad (figure 43). The openings close to the posterior margin, each opening protected by a thickened
curved ridge in front and on the side. In *alticeps* the openings are kidney-shaped and the ridges wider laterally and the confining ridges are more prominent. In *fissiceps* the openings are much as in *fissiceps* but the ridges are stronger and continued behind the openings.

*Type locality.* Not given but probably Massachusetts.

New York: Mount Marcy, summit, Aug. 29, 1922, 1♀; Mount Whiteface, Essex county, 2300 ft., Aug. 25, 1922, 1♀; Wilmington Notch, Essex county, Aug. 1916, 1♂ 3♀; Aug. 21, 1916, 3♂ 1♀; Aug. 26, 1921, 3♀; Chapel pond, Essex county, June 27, 1922, 2♀; Bumps pond, Washington county, July 28, 1920, 9♀; Cranberry Creek, Aug. 1911, 2♀; Mountain lake, Fulton county, April 26, 1923, 1♀; East bay, Wayne County, Sept. 15, 1920, 1♀; Lake Bluff, Sept. 9, 1920, 1♀; North Fairhaven, July 14, 1919, 1♀; Rock City, Cattaraugus county, July 1918, 1♀; Letchworth Park, July 9, 1922, 2♂ 10♀; Guyanoga, June 24, 1923, 1♀; Crosby, Yates county, April 1904, 1♀; Oct. 20, 1910, 2♀; Lake Keuka, June 1904, 1♂ 1♀; Dec. 1905, 1♀; Cinnamon lake, Schuyler county, July 12, 1924, 1♀; Montour Falls, Oct. 12, 1924, 2♀; Taughannock, Oct. 18, 1902, 1♂; Aug. 1918, 2♀; Mountainville, May 11, 1923, 1♀; Oakland Valley, May 26, 1920, 2♂ 3♀; Cold Spring Harbor, Aug. 8, 1907, 1♂ 4♀; July 23, 1917, 2♀ (Bryant); Oyster Bay, 9♀ (Chamberlin); Farmingdale, June 16, 1918, 1♀; Riverhead, Aug. 28, 1920, 1♀; April 11, 1923, many ♀; Great pond, Riverhead, May 23, 1924, 1♀; Long pond, Suffolk county, June 29, 1924, 1♀; Montauk Point, May 24, 1924, 1♀.

Maine: Lubec, July 30, 1913, 2♂; Isle au Haut, July 1922, 1♂ (Bowditch).

New Hampshire: Moosilauke, July 3, 1912, 1♂ 1♀ (Bryant); Intervale, July 13, 1914, many ♀ and ♀; July 20, 1914, many ♀ and ♀; Aug. 14, 1914, 5♀; July and Aug. 1915, many ♀ and ♀; Aug. 1916, 1♀ (Bryant); July 17, 1913, many ♀ and ♀.
Massachusetts: Petersham, May 27, 1913, 1♂ 1♀ (Bryant); Lake Boon, Stowe, July 17, 1916, 1♂ 1♀ (Bryant).

Connecticut: Armston, June 4, 1918, 1♂ 1♀; Storrs, July 28, 1923, 1♀.


District of Columbia: Washington, 1♂ 1♀ (Banks); July 1, 1912, 1♂ 1♀.

Virginia: Falls Church, 2♂ 5♀ (Banks).


Missouri: Columbia, Nov. 1904, 2♂ 7♀; Dec. 1904, 1♂ 2♀; May 1905, 2♂ 2♀; July 1905, 1♀; Osceola, Aug. 1905, 1♂ 1♀.

This species has also been recorded by Emerton from Quebec: Gaspe Coast, Maniwaki; Ontario: Minaki; by Barrows from Ohio: Sugar Grove; by Banks from North Carolina: Roan mountain.

**Ceraticelus formosus** Banks

Plate 5, figures 44-47


*Idionella formosa* Banks. N. Y. Ent. Soc. Jour. 1:130, 1893


*Ceratinella formosa* Emerton. Conn. Acad. Sci. Trans. 14:185, pl. 2, fig. 5. 1909

*Ceratinella formosa* Emerton. Appalachia 13:156. 1914


**Male.** Length, 1.8 mm. Cephalothorax viewed from above, rounded on the sides behind, narrowed in front of second coxae and distinctly constricted at the cervical groove, broadly rounded in front; viewed from the side, steeply ascending behind then more gradually to just back of the eyes, rounded over the top of the head. Clypeus straight, slightly protruding.

Posterior eyes in a straight line separated by about the diameter, anterior eyes in a gently procurved line, the median smaller than the lateral, separated from each other by less than the radius and from the lateral by the diameter.

Sternum and labium dark grayish brown; endites brown, grayish basally. Hind coxae separated by more than the diameter.

Abdomen has the dorsal sclerite almost contiguous with epigastric sclerite in front, thus covering the anterior end of the abdomen (figure 46); hard parts orange to brown, dorsal sclerite thickly armed with small tubercles, especially in front, soft parts grayish yellow, darker below. Epigastric sclerite lighter brown than the sternum with the posterior lateral angles short and rounded behind. Infra-mammillary sclerite distinct, confined to the ventral surface. Legs orange-yellow.
Femur of palpus rather slightly curved, patella very short. Ratio of length of femur to that of patella at 15 to 5. Tibia has the dorso-lateral apophysis extending almost at a right angle, the tip bent squarely towards the end of the palpus (figure 44). Paracymbium curved in a semicircle, the tip sharply hooked. Tailpiece of the embolic division long, spirally twisted, notched just before the tip. On emerging from the edge of the bezel the apical part of the embolus is rather broad and deeply grooved, it then curves around in a semicircle and the ejaculatory duct leaves it at an acute angle. The free part of the duct is black basally and colorless at the tip; it has a double curve but is not coiled (figure 45).

**Female.** Length, 2.1 to 2.5 mm. Resembles the male in color but the dorsal sclerite is confined to anterior part of the abdomen and in front extends back to the insertion of the pedicel where it is separated from the epigastric sclerite by a narrow suture. Middle lobe of epigynum triangular, broadly truncate in front, gently emarginate behind, and bearing on anterior part a small slightly elevated, light colored, semicircular lobe (figure 47).

**Type locality.** Ithaca, N. Y.
New York: Ithaca, Sept., 9's (Banks); Sea Cliff, 2♂ (Fox).
Maine: Long Island, Portland Harbor, Sept. 11, 1904, 2♂ 2♀ (Bryant).
New Hampshire: Carter Notch, White mountains, 1 specimen.
Massachusetts: Gloucester, Aug. 30, 1907, many ♂ and ♀. Under straw on the beach (Bryant); Winthrop Beach, Nov. 12, 1922, 1♂ 1♀. Under litter on beach.

This species has also been recorded by Emerton from Massachusetts: Provincetown, Neponset, Ipswich; Maine: Ogunquit, islands in Casco Bay, Thomaston; New Hampshire: Jackson.

**Ceraticelus laetabilis** Cambridge

Plate 5, figures 48-51

_Ceratinella laetabilis_ Emerton. Conn. Acad. Sci. Trans. 6:35, pl. 8, fig. 2. 1882
_Ceraticelus laetabilis_ Simon. Ar. Fr. 5:596. 1884
_Ceratinella laetabilis_ Emerton. Common Spiders, p. 151, fig. 368-370. 1902
_Ceratinella laetabilis_ Emerton. Psyche 16:96. 1909
**Male.** Length, 1.4 to 1.5 mm. Cephalothorax dark brown, a little lighter on the head, finely reticulate; viewed from above, rounded on the sides, strongly convergent towards the front with a distinct constriction at the cervical groove, rounded in front; viewed from the side, evenly ascending to the back part of the head and then nearly level to the posterior eyes. Clypeus slightly protruding, distinctly concave just below the eyes.

Posterior eyes in a straight line, the median separated from each other by the diameter and from the lateral by two-thirds as much. Anterior eyes in a slightly recurved line, the median smaller than the lateral, separated from each other by less than the radius and from the lateral by the diameter.

Sternum light brown, coarsely reticulate with darker brown and with a narrow smooth brown margin; labium brown; endites brownish yellow. Hind coxae separated by the length. Legs and palpi yellowish. Dorsal abdominal sclerite brownish orange, strongly chitinized and covering all but the posterior fifth of the abdomen. Epigastric sclerite well developed, the insertion of the pedicel at its center; the posterior lateral angles rounded and produced backwards only a short distance. Each epigastric plate bounded on the outside by a distinct ridge which extends to the anterior edge of the sclerite. Inframammillary sclerite grayish yellow, broad but confined to the underside of the spinnerets. Soft parts of the abdomen grayish or greenish. Femur of palpus slightly curved, thickened below; patella short, strongly bent ventrally. Ratio of length of femur to that of patella as 19 to 7. Tibia short and broad at tip, the dorso-lateral angle enlarged and provided with a black, blunt triangular tooth (figure 48); the edge of the tooth is incurved so that in profile it appears hooked and the inner edge is minutely serrate. Cymbium with a deep longitudinal furrow close to the lateral margin. Paramycymbium rather broad at base, narrow towards tip, strongly curved.

Bezel wide, rounded proximally, pointed distally. Tailpiece of embolic division long, slender and strongly curved outward at tip. On emerging from the edge of the bezel the apical part of the embolus is a slightly flattened black rod. It makes a semicircular bend and the sharp tip lies close under the edge of the tip of the cymbium. The ejaculatory duct lies in a membrane below the embolus and comes up to it some distance before the tip. It leaves it almost immediately and continues free in a double curve (figure 49). The tip lies under the edge of the bezel.

**Female.** Length, 1.7 mm. Cephalothorax similar to that of the male but the head is a little wider. The abdomen lacks the dorsal sclerite and varies in color from nearly white to grayish with an irregular light area in the middle; clothed with short hairs arising from minute brown tubercles. The epigastric sclerite divided into three parts by a suture on each side of the epigynum running forward just inside the epigastric plate to the anterior margin. The parallel ridges are on these lateral sclerites. The middle lobe of the epigynum consists of two parts, a transverse posterior part with rounded ends and a heart-shaped anterior part.
bluntly pointed in front and separated from the posterior part by a deep but narrow constriction. In front of the epigynum and near the insertion of the pedicel is a prominent transverse ridge which seen in profile slants forward (figure 50).

Type locality. Cambridge, Mass.

New York: Auger pond, Essex county, Nov. 17, 1926, 1♀; High Falls, Essex county, Aug. 26, 1921, 3♂; Wilmington Notch, Essex county, Aug. 21, 1916, 3♀; Aug. 6, 1921, 2♂ 1♂; Lake Pleasant, April 27, 1923, 3♂; Valchampain, Lake Champlain, Aug. 24, 1917, several ♂ and ♀; Letchworth Park, July 9, 1922, 1♀; Rye Point, Sept. 26, 1920; Penn Yan, May 4, 1922, 1♂ 2♀; Egleston Glen, Yates county, Sept. 24, 1920, 2♂; Lake Keuka, April 1904, 1♀; Nov. 1903, 1♀; Savona, Sept. 25, 1920, 1♀; Montour Falls, Oct. 12, 1924, 1♀; Alpine, Nov. 2, 1919, 1♂ 3♀; Interlaken, July 1904, 1♂; Taughannock falls, July 14, 1920, 1♂; Connecticut hill, Schuyler county, November 9, 1919, 1♀; Oct. 21, 1920, 2♂ 1♀; Enfield Glen, Oct. 10, 1920, 1♂ 2♀; Aug. 6, 1922, 1♀; Oct. 12, 1924, 1♂ 3♀; Ithaca, common, all months; Danby, Oct. 18, 1924, 2♂ 1♀; Cascade, Cayuga county, Nov. 15, 1915, 1♂ 3♀; Freeville, May 1911, several ♂ and ♀; Oct. 12, 1924, 2♀; McLean, Sept. 28, 1921, ♂ and ♀; Deruyter lake, July 4, 1922, 1♀; West Winfield, June 8, 1920, 1♀; Belden hill, Broome county, May 19, 1923, 1♀; Apalachin, May 19, 1923, 3♀; Meredith, May 19, 1923, 1♀; Delaware lake, Delaware county, May 20, 1923, 1♂; South Westerlo, May 19, 1921, 1♀; Pearl Point, Lake George, July 29, 1920, 1♂; Juanita island, Lake George, July 22, 1920, 2♀; Mount Utsayantha, Delaware county, October 21, 1924, 3♂ 8♀; Slide mountain, Ulster county, June 3, 1923, 1♀; May 8, 1921, 1♂ 3♀; Cragsmoor, Ulster county, May 24, 1920, 1♀; Sam’s Point, Ulster county, May 24, 1920, 1♂; Pinekill, Sullivan county, May 11, 1922, 1♂ 1♀.

New Hampshire: Franconia, 1♀ (Banks); Intervale, Aug. 1912, 1♂ 1♀; Moosilauke, July 8, 1912, ♂ and ♀.

Vermont: Ascutney, May 25, 1913, 1♂ (Emerton); Windsor, May 24, 1913, 1♂ 1♀ (Emerton); Pittsford, May 16, 1924, 1♂ 2♀.

Massachusetts: Monoponsett, June 12, 1912, 1♂ 1♀ (Emerton); Otter river, July 22, 1921, 1♀.

Pennsylvania: Loganton, Aug. 1911, 1♂.

North Carolina: Grandfather mountain, Oct. 12, 1923, 1♀; Madison, Oct. 8, 1923, 1♂.

Missouri: Columbia, Nov. 1904, 2♂; Dec. 1904, 3♂.

Minnesota: Lake Minnetonka, June 17, 1924, 1♂ (Fletcher); South Dakota: Hill City, 1♂.

Ontario: Sanford, June 1906, 1♂ 2♀.

This species has also been reported by Emerton from Massachusetts: Tyngsboro; Newfoundland: Spruce Brook and Steventville Crossing; Manitoba: Lake Winnipeg; Aweme; Alberta: Athabasca; by Banks from North Carolina: Black mountain.

Remarks. This common species is collected almost exclusively by sifting in moderately dry woods.

From the base of Mount Pisgah, South Hominy creek, Buncombe county, N. C., 3000 ft. Oct. 19, 1923, we have a puzzling series of
and $10 \varphi$. The males are a little smaller and paler than typical \textit{laetabilis} but a careful comparison of specimens shows that they are identical in structural characters. The females, however, have a different epigynum. The middle lobe consists of two parts: the posterior part is transverse, rounded on the sides and narrowed in front; the anterior part, which overlaps the posterior part, is evenly rounded on the front and sides, and broadly rounded behind.

The transverse ridge in front of the epigynum is the same as in typical \textit{laetabilis} (figure 51).

**Ceraticelus laetus** Cambridge

Plate 6, figures 52–55

\textit{Erigone laeta} Cambridge. Zool. Soc. London Proc. 1874, p. 433, pl. 55, fig. 4

\textit{Ceratinella laeta} Emerton. Conn. Acad. Sci. Trans. 6:35, pl. 8, fig. 1. 1882

\textit{Ceraticelus laetus} Simon. Ar. Fr. 5:596. 1884

\textit{Erigone laeta} Keyserling. Spinnen Amerikas, Theridiidae, 2:176, pl. 17, fig. 236. 1886


**Male.** Length, 1.4 mm. Cephalothorax dark brown, lighter on the head, very finely reticulate with black; viewed from above, rounded on the sides, narrowed toward the front, distinctly constricted at the cervical groove, rounded in front; viewed from the side, evenly and gradually ascending to the head and then gently rounded to the posterior eyes. Clypeus straight and nearly vertical.

Posterior eyes in a very gently procurred line, the median separated from each other by a little more than the diameter and from the lateral by the diameter. Anterior eyes in a straight line, the median separated from each other by less than the radius and from the lateral by two thirds the diameter.

Sternum orange-yellow suffused with brownish, darker at the margin, finely punctured, not reticulate with brown as in \textit{laetabilis}. Hind coxae separated by the length. Labium dark brown. Endites orange-yellow. Legs and palpi light orange-yellow.

Dorsal abdominal sclerite smooth, orange-yellow, lighter than the cephalothorax, strongly chitinized and covering all but one-seventh of the abdomen when viewed from above. Epigastric sclerite light orange-yellow with the insertion of the pedicel at its center; posterior lateral angles produced backward only a short distance, rounded externally and nearly square mesally; the lateral ridges not so strong as in \textit{laetabilis}. Inframammillary sclerite broad, confined to the ventral surface. Soft parts of abdomen dark gray, nearly black, with numerous small pale irregular spots.

Femur of palpus distinctly curved mesally, compressed and strongly widened distally below; patella short, strongly curved ventrally. Ratio of length of femur to that of patella as 21 to 7. Tibia short,
the dorso-lateral apophysis narrower and more pointed than in laetabilis, notched on the mesal side; margin minutely serrate (figure 55) at the middle of the dorsal margin there is a small, blunt, triangular tooth. The meso-ventral tooth smaller than in laetabilis. Cymbium with two deep curved grooves at the lateral margin separated by a sharp carina (figure 52). Paracymbium rather slender, strongly curved, pointed at tip. Tailpiece of the embolic division long, slender, strongly curved outward at the tip. The apical part of the embolus emerges from the edge of the bezel as a shining black rod which makes a semicircular spiral curve over the end of the bulb, the tip lying close to the edge of the tip of the cymbium. At the tip the ejaculatory duct leaves it at a sharp angle and curves back so the tip lies at the edge of the bezel (figure 53). The basal part of the free duct is flattened, and has two semitransparent lobes on the outer side.

**Female.** Length, 1.8 mm. Similar to the male in form and color. The abdomen without a dorsal sclerite, soft parts nearly white to dark gray, clothed with minute hairs arising from brown tubercles. Epigastric sclerite divided into three parts by sutures which run between the epigynum and the epigastric plates. The lateral ridges distinct but not so prominent as in laetabilis. Infraamamillary sclerite yellowish, confined to the underside of the spinnerets. The middle lobe of the epigynum consists of two parts: a narrow transverse posterior plate and a narrower triangular anterior part which is broadly and deeply notched behind (figure 54). The transverse ridge in front of the epigynum present but much less prominent than in laetabilis.

**Type locality.** Cambridge, Mass.

New York: McLean Bogs, May 14, 1919, 1♂ 4♀; May 30, 1921, 2♂ 4♀; June 17, 1923, 5♀.
New Hampshire: Franconia, 1♀ June 13, 1922, 2♂ 6♀; (Banks); May 30, 1919, 5♀.
This species has also been recorded by Emerton from Ontario: Ottawa.

**Remarks.** We have taken this species only by sifting moss in cold sphagnum bogs.

### Ceraticelus laticeps Emerton

Plate 6, figures 56–60, plate 12, figure 113

Ceratinella laticeps Emerton. Conn. Acad. Sci. Trans. 9:498, pl. 2, fig. 2. 1894

**Male.** Length, 1.2 mm. Cephalothorax dark reddish brown, lighter on the head, finely reticulate, viewed from above, evenly rounded on the sides with the outline of the head nearly square (figure 57); viewed from the side, steeply ascending and gently rounded to the slight depression at the cervical groove, then ascending in a straight line to the highest point which is far back of the posterior eyes; from this point obliquely truncate to the anterior median eyes (figure 60). The whole dorsal anterior part of the head
including the posterior median eyes broadly concave. Over the top of the head there is a median row of three strong, forward directed hairs. The truncate part of the head clothed with short, erect hairs. Clypeus retreating, broadly convex above and concave just above the margin. Posterior eyes in a straight or very slightly recurved line, the median separated from each other by the diameter and from the lateral by $1\frac{1}{3}$ times the diameter. Anterior eyes in a strongly recurved line, the median smaller than the lateral, separated from each other by the radius and from the lateral by $2\frac{1}{2}$ times the diameter. Sternum short and broad, rough, reddish orange, irregularly sprinkled with blackish, darkest at the margin. Hind coxae separated by more than the length. Labium same color as sternum, endites and chelicerae orange-yellow. Legs and palpi yellowish.

Dorsal abdominal sclerite reddish, slightly roughened, strongly convex and covering most of the abdomen. Epigastric sclerite strongly developed, the insertion of the pedicel back of the middle. Pedicel surrounded by a strong, raised ring back of which the surface is strongly wrinkled transversely, the lateral ridges strongly developed, convergent anteriorly; a distinct, transverse rounded lobe in front of the opening of the reproductive organs. Infra-mammillary sclerite broad, surrounding the spinnerets narrowly above.

Femur of palpus short, cylindrical, moderately curved; patella short, strongly bent ventrally. Ratio of length of femur to that of patella as 13 to 6. Tibia as long as patella, the dorsal margin is extended into a short, evenly rounded lobe; the dosro-lateral apophysis is a broad black ridge with a sharp incurved tooth at each end. In some specimens the edge of the ridge is minutely serrate; in others smooth (figure 58).

Tarsus short and rounded. Paracymbium very small, slender, nearly transparent. Tailpiece of the embolic division short and thick, curved outward at the tip. On emerging from the edge of the bezel, the apical part of the embolus is a flattened, shining black rod that makes a spiral half turn around the end of the bulb (figure 56). The tip is broad and bluntly rounded. The free part of the ejaculatory duct is thrown off before the tip; at first it is flattened, twisted and bent back on the embolus and then the more slender apical part is curled.

*Female.* Length, 1.5 mm. Similar to the male in form and color. Head square in front but not depressed as in the male. Posterior eyes in a gently procurved line, separated from each other by the diameter. Anterior eyes in a gently recurved line the median smaller than the lateral, separated from each other by less than the radius and from the lateral by the diameter.

Dorsal abdominal sclerite as in the male. Epigastric sclerite heavier than in the male; no lateral sutures, lateral ridges very distinct; the surface in front of the epigynum coarsely, transversely wrinkled; posterior lateral angles strongly produced behind, rounded. Infra-mammillary sclerite surrounding the spinnerets,
broad below. Middle lobe of epigynum small, triangular, pointed in front between the black converging lateral ridges. A high, sharp, transverse ridge in front of epigynum.

_Type locality._ Laggan, British Columbia.

New York: Ithaca, Aug. 1904, 1♂; Long pond, Suffolk county, June 29, 1924, 1♂.

District of Columbia: Washington 1♂ (Chamberlin).

Virginia: Great Falls, April 3, 1921, 1♂.

Georgia: Billy's island, Okefinokee swamp, June 1912, 2♂ 2♀.

Remarks. A specimen from the Okefinokee swamp which was killed with the palpal organ distended throws some light on the use of the dorso-lateral apophysis of the tibia. The basal haemato-docha is shorter on the distal end of the aveolus so that when it is distended it carries the genital bulb back to the base of the tarsus. The distal curve of the embolus lies in the angle between the base of the cymbium and the dorso-lateral tibial apophysis. The tip of the embolus beyond the point where the ejaculatory duct is thrown off, lies on the end of the apophysis and is held in place by the teeth at each end of the ridge (figure 59).

**Ceraticelus limnologicus** n. sp.

_Plate 7, figures 61–65_

_Male._ Length, 1.5 to 1.6 mm. Cephalothorax dull reddish orange lightly suffused with dusky especially at the margin. Head dusky. Head steeply elevated and produced forward in a single bluntly-rounded lobe (figure 63). Clypeus slightly concave just above the margin, then rounded upward to form the antero-ventral surface of the cephalic lobe (figure 64).

Posterior eyes equal, in a slightly recurved line; the median eyes separated from each other by twice the diameter and from the lateral eyes by a little less. Anterior eyes in a straight line, the median smaller than the lateral, separated from each other by less than the radius and from the lateral eyes by more than twice the diameter of the latter. Sternum reddish orange, dusky on the margin. Dorsal sclerite of abdomen distinct but not covering the entire dorsal surface, reddish orange. Soft parts orange-yellow. Legs light orange-yellow, patellae lighter. Epigastric sclerite as in _emerstoni_ except that it is more heavily chitinized and darkened; the median notch deeper. Inframammillary sclerite distinct.

Femur of palpus cylindrical, slightly curved towards tip, patella strongly bent and thickened. Ratio of length of femur to that of patella as 17 to 10. Tibia short, provided with a long, strongly bent apophysis tapering to a point, without lateral teeth but with a rounded enlargement at the base (figure 62). Cymbium strongly angulate on the back with a rounded protuberance when seen in profile. Paracymbium long, slender, tapering, with a slight hook at tip. Between the paracymbium and the edge of the cymbium there projects a slender, slightly curved, fingerlike process. Embolic division with a long, slender, curved tailpiece; the apical part slender
without grooves or branches (figure 61). The free part of the ejaculatory duct coiled in one and one-half turns.

**Female.** Length, 1.7 mm. Resembles the male in general color; head darker but the dark area is smaller and not so regularly outlined. Posterior eyes equal, in a slightly recurved line, almost equidistant, separated by the diameter of one of them. The anterior eyes in a straight line, the median eyes a little smaller than the lateral, separated by the radius and from the lateral by the diameter of the latter.

Abdomen yellowish orange without a distinct dorsal sclerite. Epigynum has the middle lobe evenly rounded in front. On the anterior part there is a small elevated area rounded behind; back of this the lobe is crossed by a curved dark line just back of which on the sides, are the openings of the spermathecae. The ducts of the spermathecae show prominently as two crescent-shaped spots in front of the middle lobe (figure 65).

Holotype ♂. Allotype ♀.

**Type locality.** Crusoe lake, near Savannah, N. Y., 3♂ 1♀, May 18, 1919. Sifting in damp woods.

Maryland: Riverdale, Sept. 16, 1924, 2♂ 1♀. In sphagnum moss (H. S. Barber.)

**Ceraticelus micropalpis** Emerton

Plate 7, figures 66–71

**Ceratinella micropalpis** Emerton. Conn. Acad. Sci. Trans. 6:36, pl. 8, fig. 5. 1882

**Ceraticelus micropalpis** Simon. Ar. Fr. 5:596. 1884


**Male.** Length, 1.4 mm. Cephalothorax brown with fine blackish reticulations; viewed from above, evenly rounded on the sides, scarcely constricted at the cervical furrow, narrowed and rounded in front; viewed from the side, rather evenly arched over the back to the posterior eyes. Clypeus nearly straight, slightly retreating. Posterior eyes in a straight line, separated from each other by two-thirds the diameter and from the lateral by a little less. Anterior eyes in a straight line, the median not smaller than the posterior median, separated from each other by less than the radius and almost touching the lateral. Sternum dark brown, darker at the margin, finely reticulate; labium dark brown; endites brownish-yellow; legs and palpi yellowish. Dorsal abdominal sclerite large, orange, finely reticulate, strongly chitinized and covering most of the abdomen but does not extend quite so far back as in \textit{minutus}, epigastric sclerite larger and extending farther back than in \textit{minutus} being separated from the inframammillary sclerite by a very narrow strip of soft integument (figure 71). The soft area back of the
epigastric furrow is smaller than in minutus. The ridges extending forward from the epigastric plates in minutus are lacking in micro-palpis. The inframammillary sclerite wider than in that species. Femur of palpus slightly compressed, and curved inward; patella short and strongly bent ventrally; tibia of much the same form as in minutus but both apophyses are shorter and do not stand out at so great an angle (figure 70). The tarsus is shorter than in minutus. The genital bulb has much the same structure (figures 66–67). Ratio of length of femur to that of patella as 10 to 6.

**Female.** Length, 1.4 mm. Similar to the male in form and color. The head a little broader and lower. Dorsal abdominal sclerite a little shorter. Epigastric sclerite much like that of the male but the area of soft integument back of the epigastric furrow is larger and semicircular; the posterior margin is gently emarginate and there is a wider band of soft integument between it and the inframammillary sclerite (figure 69). The latter is a little narrower than in the male. Epigynum of the same general form as that of minutus but the middle lobe is narrower, triangular, with the apex truncate; the fingerlike structure in front of it broader and shorter. The transverse ridge in front of the fingerlike structure is longer (figure 68).

**Type locality.** West Quincy, Mass.

New York: Ancram, June 11, 1919, 2♀; Barneveld, 1919, 1♂ (Wolcott). Banks (1892) recorded the species from Ithaca, and (1895) Long Island.

Massachusetts: Winthrop beach, Nov. 12, 1922, 1♂.

District of Columbia: Washington, May 1, 1924, 2♀.


Missouri: Columbia, Mar., 2♀; Oct., 1♂; Nov., 1♂.

Kansas: Blue Mound, Douglas county, 1924, 1♀ (Beamer).

**Ceraticelus minutus** Emerton

Plate 8, figures 72–78

*Ceratinella minuta* Emerton. Conn. Acad. Sci. Trans. 6:36, pl. 8, fig. 4. 1882

*Ceratinella minuta* Banks. Phila. Acad. Nat. Sci. Proc. 1892, p. 31, pl. 2, fig. 60, pl. 4, fig. 60


*Ceratinella minuta* Barrows. Ohio Jour. Sci. 18:302. 1918


**Male.** Length, 1.2 mm. Cephalothorax brown with fine blackish reticulations. Viewed from above, evenly rounded on the sides, slightly constricted at the cervical furrow and rounded in front. Viewed from the side, evenly arched over the back to the posterior
eyes. Clypeus straight, slightly retreating. Posterior eyes in a gently recurved line, the median separated from each other by a little less than the diameter and from the lateral by the radius. Anterior eyes in a gently recurved line, the median as large as the posterior median, almost touching, narrowly separated from the lateral. Sternum brown, dark at margin, finely reticulate. Endites light brown. Legs light brown, patellae pale.

Dorsal abdominal sclerite grayish orange, finely reticulate and covering nearly the whole abdomen. Epigastric sclerite very large, oval, with the insertion of the pedicel at its center. On each side a distinct ridge extends from the lateral margin of the epigastric plate to the anterior margin of the sclerite (figure 76). Posteriorly the lateral angles of the sclerite are prolonged and coalesce leaving a small triangular area of soft integument behind the epigastric furrow. Inframammary sclerite strongly chitinized, surrounding the spinnerets as a ring. Soft parts of abdomen grayish.

Femur of palpus cylindrical, distinctly curved mesally at the base; patella strongly curved ventrally. Ratio of length of femur to that of patella as 10 to 6. Tibia short and broad; the dorso-lateral apophysis stout with an incurved tip (figures 73 and 74). On the ventro-mesal side there is a small sharp tooth. Paracymbium strongly bent, sickle-shaped. Bezel prolonged into a point toward the tip of the palpus. Tailpiece of the embolic division nearly straight, flat, tip pointed, slightly curved outward. The apical part of the embolus arises from the edge of the bezel and is arched across the face of the bulb; it then forms a short spiral and is somewhat flattened and enlarged at the point where the ejaculatory duct becomes free (figures 72, 75). The latter is curved back over the preceding part of the embolus and the tip lies proximad of the first turn on leaving the bezel.

Female. Length, 1.3 mm. Very similar to the male in form and color. There is considerable variation in the form of the epigastric sclerite. In some specimens the posterior-lateral angles are produced backwards and coalesce almost as much as in the male, in others they only touch at the tip, while in a few they do not meet (figure 77). The triangular area of soft integument is larger than in the male. Middle lobe of the epigynum broad and short, deeply emerginate in front, each side being bounded in front by a curved ridge (figure 78). In front of the middle lobe there is a concavity in which lies a narrow finger-like structure. In front of the latter is a short transverse ridge.

Type locality. New Haven, Conn.

New York: Raquette Falls, Franklin county, Aug. 24, 1922, 1♀; Elizabethtown, Aug. 21, 1921, 2♂ 1♀; High Falls, Essex county, Aug. 26, 1921, 1♂ 1♀; Wilmington Notch, Essex county, Aug. 26, 1921, 2♀; Lake Pleasant, April 27, 1923, 2♂ 4♀; Mountain lake, Fulton county, April 26, 1923, 1♂ 5♀; Gilman lake, Hamilton county, April 27, 1923, 1♀; Sylvan Beach, July 1904, 1♀; Lake Bluff, Wayne county, Sept. 19, 1920, 1♀; Wolcott, May 23, 1923, 1♂; Newfane, Oct. 1915; Mendon, Oct. 14, 1924, several
Ceraticelus nesiotes Crosby

Plate 8, figures 79-82

Ceraticelus nesiotes Crosby. Calif. Acad. Sci. (Ser. 4) 12:641, figs. 81-84. 1924.

Male. Length, 1.5 mm. Cephalothorax light brownish yellow; area covered by the base of the abdomen sharply limited in front by a curved row of minute, brownish, setigerous tubercles; on the
STUDIES IN NEW YORK SPIDERS

median line there are three larger hairs curved forward. Seen from the side, the cephalothorax is rather steeply acclivous and slightly concave posteriorly, dorsally nearly level, and in front curves down to the eyes. Head not separately elevated. Viewed from above, the cephalothorax is rather broad, rounded on the sides, convergent in front, not constricted. Eye area not black, but the eyes surrounded by narrow black rings; the anterior median on a common black spot. Clypeus slightly convex and slightly protruding. Posterior eyes in a straight line, separated by about their diameter, the median slightly nearer to each other than to the lateral; anterior eyes in a straight line, the median smaller than the lateral, subcontiguous, separated from the lateral by about the radius of a median. Sternum yellow slightly tinged with brown, the narrow margin brown; as broad as long, produced between the hind coxae which are separated by their length, squarely truncate posteriorly. Labium darker than sternum. Endites brownish yellow. Endites and sternum sparsely clothed with hairs arising from minute brownish tubercles. Chelicerae darker than the endites. Legs and palpi light brownish yellow, patellae paler than the other segments. Soft parts of abdomen nearly white, dotted with minute, brown, piliferous tubercles. Dorsal sclerite orange-yellow, restricted to the anterior two-thirds of the abdomen; narrower than the abdomen, the lateral margin serrate; anteriorly it extends over the front of the abdomen down to the pedicel; in front it appears rugose due to the stronger development of the piliferous tubercles (figure 82). Epigastric plates well developed. On each there is a bean-shaped area in which the surface is finely striate. This area is opposed to a small tooth borne on the posterior distal angle of the hind coxa and doubtless serves as a stridulating organ. Inframammillary sclerite broad below, but narrow on the sides and above the spinnerets. The tibia of the palpus has a rather long, cylindrical, blunt process on the dorso-lateral angle. This is bent so as to lie nearly parallel to the axis of the segment (figure 80). The palpal organ is of the type characteristic of the genus. The embolus makes a sharp turn at the point where it is joined by the ejaculatory duct. From this point the duct follows it closely to the tip (figure 79). Paracymbium flat and curved into a semicircle.

Female. Length, 1.5 mm. Similar to the male in coloration. Dorsal sclerite confined to the anterior surface of the abdomen and when viewed from above visible merely as a narrow crescent. Epigastric plates separated from the sclerite bearing the epigynum by narrow but distinct intervals in which the integument is white like the rest of the abdomen. Inframammillary sclerite transverse, not extended along the sides of the spinnerets. The epigynum has a broad median depression squarely truncate in front and wider behind than in front, sides nearly straight. Anterior part of the depression occupied by a transverse sclerite, convex behind (figure 81). 

Type localities. Williard’s point bay, Tiburon island and Palm Canon, Angel de la Guarda island, Gulf of California, Mexico. 3♂ 5♀.
Ceraticelus ornatulus n. sp.

Plate 8, figure 83; plate 9, figures 84–85

Male. Length, 1.8 mm. Cephalothorax orange with gray spot on the back of the head; rather broad behind, rounded on the sides, narrowed towards the front; squarely truncate in front, eyes occupying the whole width of head. Cephalothorax viewed from the side gradually ascending to the posterior eyes with a slight depression at the cervical groove. Clypeus straight, nearly vertical.

Posterior eyes in a gently procurved line, the median separated from each other and from the lateral by a little less than the diameter, anterior eyes in a gently procured line, the median much smaller than the lateral, separated from each other by one-third the diameter and from the lateral by two-thirds the diameter.

Sternum orange suffused with gray, darker towards the margin; broad, scalloped opposite the coxae. Posterior coxae separated by the length. Labium dark gray. Endites orange-yellow slightly suffused with grayish. Legs and palpi light orange yellow, the coxae somewhat grayish.

Abdomen with a large, heavily chitinized sclerite, dark brown, almost black, densely punctate and clothed with short hairs. Epigastric sclerites widely separated and extending only a short distance back of the furrow. Above the pedicel there is a semicircular sclerite, distinctly concave and bearing on each side a pair of stiff bristles. Inframammillary sclerite large but not very strongly chitinized. Femur rather thick, strongly bent mesally; patella short and thick, about as long as tibia.

Tibia short with the distal margin dorsally produced into a very short, broadly rounded lobe; dorso-laterally armed with a short black incurved tooth (figure 85). Cymbium with a single groove along the edge. Paracymbium strongly and evenly curved, nearly in a semicircle. Bezel at the end towards base of segment, produced into an erect, rounded process. Tailpiece of embolic division bent spirally, the tip extending beyond edge of cymbium. The apical part after emerging from the edge of the bezel curves over and passes under the edge of the cymbium where it turns nearly at a right angle and after making an arch over the end of the genital bulb, the tip lies near the first turn of the apical part (figure 84).

Female. Length, 1.8 to 2.2 mm. Cephalothorax and legs much as in the male. Abdomen with a large dark brown dorsal sclerite. Soft parts of abdomen greenish gray. Epigynum a large convex plate, with a broad and deep rounded emargination behind in which the median lobe appears as a rounded plate. The latter is marked with blackish on the sides giving it a quadrate appearance under low power. On the front margin of the epigynum there is a small transverse oval opening (figure 83).

Holotype male. Allotype female.

Ceraticelus paludigena n. sp.
Plate 9, figures 86-91

Male. Length, 1.5 mm. Cephalothorax orange-yellow, grayish in the eye region; viewed from above, rather broad, evenly rounded on the sides, convergent in front of third coxae; bluntly rounded on the front of the cephalic lobe bearing the posterior median eyes (figure 90); viewed from the side, arched over the back to the posterior eyes, with depression at the cervical groove; deeply excised in front of posterior median eyes. The cephalic lobe extends forward and upward and bears the anterior median eyes on the front; the upper and posterior side of the lobe is densely clothed with short recurved hairs (figure 89). Clypeus very wide, retreating and gently and evenly concave.

Posterior eyes in a recurved line, the median separated from each other by the radius, separated from the lateral by \( \frac{1}{3} \) times the diameter. Anterior eyes in a procurved line, the median eyes small and close together on the front of the anterior cephalic lobe and widely separated from the lateral.

Sternum, labium and endites orange-yellow, slightly suffused with dusky. Posterior coxae separated by the diameter. Legs and palpi pale straw color.

Abdomen provided with a distinct dorsal sclerite on the anterior half, yellowish. Epigastric and inframamillary sclerites pale yellowish, not strongly chitinized. Soft parts of abdomen pale, straw color, nearly white. Anterior spinnerets brown, posterior and adjoining integument blackish. Femur of palpus rather thick, slightly curved; patella long, thicker than femur, somewhat bent, distinctly enlarged at basal third and then gradually widened to the tip; tibia short, angulate ventrally and provided with a long, slender, dorsal apophysis the tip of which is sharp and slightly bent towards the cymbium. At the basal third of the apophysis on the side next the cymbium there is a large semitransparent scooplike structure (figure 88). The cymbium short, only moderately angulate on the back, the dorsal ridge armed with a row of short toothlike, curved hairs (figure 86). Paracymbium long, slender, hooked at tip. Bezel pointed towards tip of palpus. Tailpiece of embolic division long and slender, somewhat twisted and curved outward at tip. Soon after the embolus emerges from the edge of the bezel it bears a short, sharp, toothlike branch. Beyond this point the embolus is somewhat grooved and twisted with the tip sharp pointed. A short distance from the tip the ejaculatory duct leaves the embolus at an acute angle and after making two spiral turns the tip lies under the edge of the bezel (figure 87).

Female. Length, 1.4 mm. Cephalothorax orange-yellow with a distinct black area including the eyes; the black extending only a short way down on the clypeus; viewed from above, rounded on the sides, narrowed in front and slightly constricted just back of the eyes; viewed from the side, rounded over the back to the posterior eyes with a slight depression at the cervical furrow. Clypeus nearly vertical, distinctly concave below the eyes.
Posterior eyes in a recurved line, the median separated from each other by less than the radius and from the lateral by twice as much; anterior eyes in a slightly procurred line, the median smaller than the lateral, separated from each other by less than the radius and from the lateral by the diameter.

Sternum, labium, endites, legs and palpi colored as in the male. Abdomen nearly pure white without dorsal sclerite. Ventral sclerite feebly developed. Spinnerets dark. The epigynum consists of a nearly square middle lobe. The openings are large, rounded laterally and angulate mesally. The outer margin is not thickened but the meso-posterior caudal side, next to the middle lobe, has a dark colored strongly chitinized margin (figure 91). The ducts show distinctly; they lie along in front of the inner half of the openings and form an obtuse angle.

Holotype male. Allotype female.

Georgia: Billy's island, Okefenokee swamp, June 1912.

Ceraticelus parvulus Fox

Erigone (Ceratinella) parvula Fox. Ent. Soc. Wash. Proc. 2:45. 1891

We have not been able to recognize this species. The Fox description is as follows: Male, size 1 mm. Head rounded and elevated. Cephalothorax falls off abruptly at posterior half. Abdomen with dorsal and anterior shield, the latter almost entirely above pedicle of body. Palpus, patella as broad as long; tibia broader than long, with tooth in center and short process at outer side. Palpal organ simple, tube coiled upon itself at the end.

Colors, soft parts gray, hard parts dark brown; legs, yellowish brown.

Locality. Hollis, N. H., August.

Ceraticelus paschalis n. sp.

Male. Length, 1.5 mm. Cephalothorax yellow-orange with the posterior cephalic lobe dusky; viewed from above, evenly rounded on the sides and tapering in front to a rounded point and slightly constricted opposite the anterior median eyes; viewed from the side the outline is gently curved over the back to the base of the posterior cephalic lobe. The latter is rather low, flat on top, slanting behind and separated from the anterior lobe by a deep transverse groove. The posterior median eyes are borne well in front on the sides of the lobe. The anterior lobe is smoothly rounded, projects forward and bears the anterior median eyes on the upper slope; viewed from in front, the anterior lobe is seen to be hollowed out above along the furrow so that the posterior lobe rests in the concavity. The clypeus is very strongly convex.

Posterior eyes in a strongly recurved line, the median borne on the sides of the lobe in front of its middle, nearer to each other, than to the lateral. Anterior eyes in a slightly recurved line.
The sternum, endites, labium and chelicerae yellow-orange. Legs and palpi pale yellowish, dusky distally; tarsus of the palpus dusky. Dorsal abdominal sclerite well developed, yellow-orange, tinged with dusky on the sides. Epigastric sclerite well developed and surrounds the pedicel. Mammillary sclerite is confined to the under side. Soft parts of the abdomen yellowish white, more or less suffused with dusky.

Palpus similar to that of *fissiceps* but the patella is three-fourths as long as the femur; the tibial apophysis is shorter and the cymbium is not so sharply angulate (figures 92-93).

**Female.** Length, 1.6 mm. Similar to the male. The eye area black but the black does not extend back on the head as in *fissiceps*. The abdomen pale yellowish-orange suffused with dusky and without a dorsal sclerite. Epigynum similar to that of *fissiceps*, but the middle lobe is larger and more nearly square (figure 94).

Holotype male. Allotype female.

Virginia: Great Falls, April 3, 1921, 2♂ 7♀.


**Ceraticelus pygmaeus** Emerton

Plate 10, figures 95-97

*Ceratinella pygmaea* Emerton. Conn. Acad. Sci. Trans. 6:34, pl. 7, fig. 4. 1882


*Ceraticelus pygmaeus* Simon. Ar. Fr. 5:596. 1884


**Male.** Length, 1.5 mm. Cephalothorax orange-yellow, eye area blackish, the black extending back to a point at the dorsal furrow. Cephalothorax viewed from above evenly rounded on the sides without a constriction at the cervical groove, narrow and rounded in front; viewed from the side gently arched to the posterior eyes. Clypeus very wide, slightly concave, nearly vertical.

Posterior eyes in a gently recurved line, separated from each other by a little less than the diameter. Anterior eyes in a gently recurved line, the median smaller than the lateral, less than the radius apart, separated from the lateral by the diameter.

Sternum orange-yellow, suffused with brownish along the margin; margin with a narrow smooth brownish band. Labium brownish; endites and chelicerae yellowish. Legs pale yellowish; the tibiae darkened, the posterior pair nearly black.

Dorsal abdominal sclerite orange-yellow, well developed but not covering the whole abdomen. Epigastric sclerite orange-yellow, transversely wrinkled between the epigastric plates; the posterior
lateral angles produced only a little back of the opening of the reproductive organs. Inframammillary sclerite broad below, narrower on the sides, not continuous above the spinnerets. Soft parts of abdomen white, clothed with short, fine hairs arising from minute tubercles.

Femur of palpus slender, cylindrical, only slightly curved; patella long and much thicker than the femur. Tibia very short, armed with a very long dorso-lateral apophysis which is bent at a right angle towards the tip and armed with a very strong tooth on the inside of the basal half (figure 95). Back of cymbium strongly carinate and acutely angulate (figure 96). Paracymbium very long, slender, nearly straight, thickened basally and slightly hooked at the tip. Tailpiece of the embolic division long, slender toward tip and moderately curved. Apical part of the embolus on emerging from the edge of the bezel broad and grooved, sharply curved and twisted, the tip pointed. The free part of the ejaculatory duct leaves it before the tip and is curved back in a spiral.

**Female.** Length, 1.5 mm. Similar to the male in form and color but the black triangular area on the head is not so distinct and the head is more rounded in front. Dorsal abdominal sclerite much smaller than in the male. Epigastric sclerite divided into three parts by longitudinal sutures. Epigynum has the middle lobe consisting of two parts; a short posterior part and a much larger nearly square anterior part; the edges of the latter are dark brown. These brown edges extend briefly around the hind angles and each curves a third of the way across the anterior margin (figure 97). The brown edges are the most conspicuous feature of the epigynum and look like a pair of brackets [ ].

**Type locality.** Pine swamp, New Haven, Conn.

New York: Sea Cliff, 1♂ (Banks); Cold Spring Harbor, April 8, 1905, 1♂ 1♀ (Bryant). Banks's Ithaca record is very doubtful. He figures the epigynum but it looks like that of minutus.

Virginia: Falls Church, 2♂ (Banks).

District of Columbia: Washington, 1♂. The palpus of the type of C. melancnemis Fox. Fox records the species from Washington in May and October.

**Ceraticelus similis** Banks

Plate 10, figures 98–102

*Ceratinella similis* Banks. Acad. Nat. Sci. Phila. Proc. 1892, p. 31, pl. 5, figs. 61a, 61b


*Ceratinella similis* Banks. U. S. Nat. Mus. Bul. 72, 1910, p. 25

*Ceratinella similis* Banks. U. S. Nat. Mus. Hist. 29:221. 1911. Recorded as synonym of *Ceraticelus emertoni*.


*Ceraticelus nubiliceps* Chamberlin. U. S. Nat. Mus. Proc. 63: 8–9, pl. 2, fig. 16. 1924
Male. Length, 1.6 mm. Cephalothorax light yellowish orange, head dusky, darker around the anterior median eyes; an irregular dusky mark in front of the dorsal groove; viewed from above, evenly rounded on the sides and broadly rounded in front (figure 101); viewed from the side, evenly rounded over the back, ascending to the posterior eyes; clypeus retreating, convex below the eyes and concave below; the head an evenly rounded single lobe (figure 100).

Posterior eyes in a slightly recurved line, equal, the median separated by $\frac{3}{4}$ times the diameter and a little nearer the lateral. Anterior eyes in a slightly recurved line, the median separated by the radius, and twice their diameter from the lateral.

Sternum yellowish orange diffused with dusky, darker at the margin. Endites and labium dusky yellowish orange, lighter distally. Legs and palpi yellowish. Abdomen provided with a distinct yellowish orange sclerite. Epigastric sclerite yellow, well developed; the inframamillary less distinct, yellowish. Femur of palpus cylindrical, nearly straight; patella short, broad and strongly curved. Length of femur to that of patella in the ratio of 16 to 10. Tibia short and provided with a broad, flat, strongly curved, sharp-pointed apophysis (figure 98); on the outside it is squarely angulate at base, and bears a small tooth on the inside.

Paracymbium long and slender, thicker near the base, slightly hooked at the tip. Bezel roughened, rounded at tip, constricted at middle. Embolic division has the tailpiece rather thick at base, narrowed distally and curved outward at tip; the apical part is heavy and strongly grooved and widened just before the point where the ejaculatory duct breaks off; the tip is slender and bluntly rounded (figure 99). There is no lateral branch as in emertoni. The free part of the ejaculatory duct makes one and one-half turns.

Female. Length, 1.6 mm. Similar to male in coloration. The black on the cephalothorax confined to the head. Abdomen without a dorsal sclerite, pale yellowish white.

Epigynum differs from that of emertoni in that the ducts of the spermathecae make an acute instead of a right angle with the confining ridges of the openings (figure 102).

Type locality. Six Mile creek, South Hill, Ithaca, N. Y. Nov.-April.

New York: Ithaca, Oct. 6, 1912, 1♂ 1♀; Sept. 2, 1919, 1♂; Sept. 16, 1919, 1♂; Ringwood, Tompkins county, July 16, 1922, 3♀; Clayville, June 8, 1921; Poughkeepsie, 1♂ 1♀ (Banks); Bridgehampton (Ocean Beach), Aug. 28, 1920, many ♀ and ♀; Wading river (Sound beach), June 16, 1919, 2♂ 20♀; Riverhead (Sound beach), Sept. 10, 1922, many ♀ and ♀; Sea Cliff (Emerton); Cold Spring Harbor, July 3, 1907, 1♀; July 23, 1907, 1♀; Aug. 10, 1907, 1♂; Aug. 9, 1907 (Bryant); Oyster Bay, 1♂ 6♀ (Chamberlin).

New Hampshire: North Woodstock, Sept. 1911, 1♂ (Fox).

Massachusetts: Winthrop Beach, Nov. 12, 1922, 1♂. Cambridge (Emerton).

Ohio: Columbus, May 24, 1916, 1♂ 1♀ (Barrows); Apr. 13, 1916, several ♀ and ♀ (Barrows); Rock Bridge, May 4, 1918, 1♂ (Barrows).
Pennsylvania: President, July 4, 1922, 1♂ 3♀.

**Ceraticelus tibialis** Fox

Plate 11, figures 103-105


**Male.** Length, 1.3 mm. Cephalothorax reddish orange, blackish on the eye area; viewed from above, rounded on the sides, slightly constricted at the cervical furrow, narrow and rather pointed in front; viewed from the side, rather steeply ascending behind, then more gradually ascending to just back of the posterior eyes with a slight depression at the cervical groove, rounded over the head to the anterior eyes. Clypeus wide, slightly concave, strongly retreating.

Posterior eyes in a recurved line, the median separated from each other by the diameter and from the lateral by two-thirds the diameter. Anterior eyes in a straight line, the median smaller than the lateral, separated from each other by less than the radius and from the lateral by more than the diameter. Sternum broad, orange-yellow, labium darker at tip, endites paler than the sternum. Hind coxae separated by more than the length. Legs and palpi light brownish yellow.

Dorsal abdominal sclerite orange, smooth with shallow setigerous punctures, large and strongly chitinized, covering most of the abdomen. Epigastric sclerite orange-yellow with the posterior lateral angles scarcely produced backwards, broadly rounded. Infra�ammillary sclerite broad and heavy, surrounding the spinnerets on three sides.

Femur of palpus rather slender, somewhat wider distally; patella short, strongly curved ventrally. Ratio of length of femur to that of patella as 14 to 7. Tibia very short, armed with a very long, slender, strongly curved dorso-lateral apophysis, the base of which is abruptly wider and armed with a strong sharp tooth on the inner side (figure 104). Paracymbium rather broad at base, slender apically and with a short hook at the tip. Bezel high, upper margin nearly straight, proximal angle square. Tailpiece of the embolic division very long, slender, evenly curved and pointed at the tip. The apical part of the embolus on emerging from the edge of the bezel rather broad and grooved, curved in a semicircle. It throws off a short blunt-pointed branch on the outside of the curve at its middle. The free part of the ejaculatory duct leaves the embolus before the tip and forms nearly two spiral curves with the tip lying at the edge of the bezel (figure 103).

**Female.** Length 1.4 mm. Similar to male in form and color but paler. Abdomen without dorsal sclerite, nearly white, clothed with short hairs arising from minute brownish tubercles. Epigastric sclerite divided into three parts by sinuous sutures. Middle lobe of
the epigynum transverse with oblique, earlike projections on the anterior angles (figure 105). Front part of the epigynum transversely wrinkled but without the ridge.

Type locality. District of Columbia.
Virginia: Falls Church, 1σ 1♀ (Banks).
District of Columbia: Washington, 1σ (Chamberlin).

Ceraticelus titivillitium n. sp.

Plate 11, figures 106-109

Male. Length, 1 mm. Cephalothorax brown mottled with blackish, surface finely reticulate, viewed from above, broad, rounded on the sides, narrowed in front and scarcely restricted back of the eyes; viewed from the side steeply ascending behind, and then gently arched to the posterior eyes. Clypeus narrow, somewhat retreating and distinctly and regularly concave.

Posterior eyes in a straight line, separated by about the diameter; anterior eyes in a gently recurved line, the median smaller than the lateral, very close together and separated from the lateral by less than the diameter. Sternum short and broad, rugulose, brown mottled with blackish; endites grayish brown. Hind coxae separated by more than the length. Legs and palpi pale yellowish.

Abdomen with a brownish dorsal sclerite on anterior two-thirds. Epigastic sclerite highly developed, extending back half way to the spinnerets and forward so as to reach nearly the dorsal sclerite (figure 107). Inframammillary sclerite broad, distinct. Soft parts of abdomen gray. Spinnerets pale.

Femur of palpus slender, slightly curved; patella, broader than femur. Tibia short, the dorso-lateral apophysis broad and thin and armed on the inner side with a small sharp black tooth and on the truncate tip with three minute teeth (figures 108 and 109). The bezel not greatly widened. Tailpiece of the embolic division rather short, broad, flat and bluntly pointed. The embolus emerges from the edge of the bezel as a black rod which makes an S-shaped curve before reaching the edge of the cymbium. At this point the ejaculatory duct becomes free and lies curled across the end of the genital bulb (figure 106).

Holotype male.
Georgia: Billy’s island, Okefinokee swamp. June 1912, 2♂. Collected by sifting decaying leaves in dense shade at edge of swamp.

THE AFFINITIES OF THE SPECIES OF CERATICELUS
While the forms here placed in Ceraticelus form a homogeneous and clearly defined group, the degree of similarity varies considerably among the various species. The relationship of the species may be roughly indicated by arranging them in the following groups:

The fissiceps group, including: bulbosa, alticeps, atriceps, paludigena, and paschalis. This group is characterized by the development of cephalic lobes in the male, by the angulate and carinate back of the cymbium and by the long slender and toothed tibial apophysis. In two species, fissiceps
and paludigena, the cephalic lobes are divergent and do not touch at apex while in the other four species the lobes are broadly touching, leaving a cavity between them, sometimes appearing as a round hole through the head.

The emertoni group, including: creolus, similis, limnologicus, pygmaeus, and fastidiosus. This group is characterized by the development of the head into a single, rounded, forward-projecting lobe. The tibial apophysis is broader than in the fissiceps group and is strongly incurved. The apical part of the embolic division is stout, grooved, and spirally twisted and is sometimes armed with a branch or tooth. We place fastidiosus in this group because of the structure of the embolic division although the head is not produced forward. C. fastidiosus and C. pygmaeus resemble each other in having the back of the cymbium strongly angulate.

The laetabilis group, including: laetus and carinatus. This group is characterized by having the head normal, the integument more strongly chitinized and the apical part of the embolic division, slender and stylelike, semicircularly curved across the end of the bulb, and throwing off the ejaculatory duct at or just before the tip. The tibial apophysis is short.

The minutus group, including: micropalpus and titivillitium. This group is closely related to the preceding and is characterized by the still stronger chitinization of the integument and by the minute size. The free part of the ejaculatory duct is very long and sinuous, but not coiled. Tibial apophysis short.

In the formosus group, including nesiotes, the head is normal, the tibial apophysis is large and extends at a right angle to the tibia and then bends forward. The abdominal sclerite is especially developed anteriorly.

The distribution of these two species is of interest; formosus is found most abundant on the beach of the North Atlantic coast while its nearest relative, nesiotes, is found in similar situations on the Gulf of California in Mexico.

There remains three species which do not fall into any of the above groups. C. ornatus reminds one of Ceratinella brunnea in the form of the genital bulb but it lacks the double curve in the claw of the chelicera. C. tibialis is related to the fissiceps group by the form of the embolus but the apical part bears a very long branch as in some members of the emertoni group. The tibial apophysis is slender and longer than in any species known to us. Laticeps is the most aberrant form which we have placed in the genus. The tailpiece of the embolic division is shorter and of different form. The broadly depressed eye region separates it distinctly from the other members of the genus.
EXPLANATION OF PLATES

Plate 1

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Figure 1 Ceratinella brunnea. Right palpus, lateral view.
Figure 2 Ceratinella placida. Left palpus, mesal view.
Figure 3 Ceratinella placida. Left palpus, dorsal view.
Figure 4 Ceratinella sphaerica. Right palpus, ventral view.
Figure 5 Ceratinella sphaerica. Male, dorsal view.
Figure 6 Ceratinella sphaerica. Right palpus, lateral view.
Plate 2

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Figure 7  Ceratinella sphaerica. Male, lateral view.
Figure 8  Ceraticelus albus. Right palpus, mesal view.
          After Crosby from balsam mount of type.
Figure 9  Ceraticelus albus. Tibial apophysis.
Figure 10 Ceraticelus alticeps. Male, dorsal view of cephalothorax.
Figure 11 Ceraticelus alticeps. Right palpus, lateral view.
Figure 12 Ceraticelus alticeps. Right palpus, ventral view.
Figure 13 Ceraticelus alticeps. Male, lateral view of cephalothorax.
Figure 14 Ceraticelus alticeps. Epigynum.
Figure 15 Ceraticelus atriceps. Epigynum.
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