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## GEOLOGY 6

# GEOLOGY OF THE VICINITY OF LITTLE FALLS, HERKIMER COUNTY

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## GEOLOGY OF THE VICINITY OF LITTLE FALLS, HERKIMER COUNTY

AREA COMPRISED IN THE LITTLE FALLS QUADRANGLE

### PREFACE

The study of the crystalline rocks of the Adirondack area by modern petrographic methods was begun in 1892 by Prof. J. F. Kemp under the direction of the writer in connection with the iron ore deposits in the vicinity of Port Henry and some results were published in Museum bulletin 14, *Geology of Moriah and Westport Townships, Essex County, N. Y., with notes on the iron mines.* Subsequently this work was continued and extended under the direction of Prof. James Hall, and Professors C. H. Smyth jr and H. P. Cushing were invited to participate in the study of this great crystalline area. The work of the three investigators in their separate fields has been published in the reports of the state geologist for 1893 and subsequent years, and has resulted in a wholly new light being thrown on the structure and geologic history of the district. Professor Cushing's special field has been the Northeastern Adirondacks and having successfully covered the part alloted to him so far as the existing maps of that region would permit, it seemed that it would be of much interest to make a detailed comparison of the northern pre-Cambrian geology with that of an area bordering on the Mohawk valley. The Little Falls quadrangle having been completed, this suggested itself as a convenient and interesting field for work. Professor Cushing accordingly, as a result of a careful study of this area, communicates the following report.

FREDERICK J. H. MERRILL
*State Geologist*

## GEOGRAPHIC POSITION

The area comprised in the Little Falls atlas sheet lies mostly north of the Mohawk river between East Canada and West Canada creeks. The Mohawk runs across the sheet near its southern edge. The Canada creeks diverge and run out of the sheet limits, East Canada to the east, and West Canada to the west, about midway between the Mohawk and the north border of the sheet. The map extends over 15′ of latitude, 43° to 43° 15′ n., and 15′ of longitude, 74° 45′ to 75° w., comprising about 218 square miles.

Its geographic association is with the Adirondack highland region and the Mohawk valley lowland. South of the Mohawk the altitude rises quickly to that of the dissected plateau region of southern New York, this being wholly without the map limits. The lowland is worn down on a belt of rocks which are weak as compared with those to the north and the south. It is much narrower here than farther west, for the reason that rocks which here are resistant and hence belong to the plateau district, become both weaker and thicker as they are followed to the west, so that the belt which they underlie becomes merged with that of the lowland.

The lowland belt is an agricultural one and has been cleared and farmed this many a year. The district occupying the northeast portion of the map belongs however with the Adirondack highland belt and is still forest covered. But lumbering has been carried on for many years around the edge of the woods, so that within the limits of the map the timber has been mainly cut and the woods are therefore very thin. Fires have however not been as frequent as in many parts of the Adirondacks, and very little of the territory has been burned over. Sporadic cutting of timber is going on even yet, mainly hardwood, with here and there a spruce, the logs being hauled out singly throughout the year. The supply is sufficient to keep several small sawmills running.

## GENERAL GEOLOGY

The detailed topography of the district can not be made intelligible without a knowledge of the rock structure and the geologic history of the region, since it depends on both. The study of the rocks has brought out the facts here given and the detailed evidence will be presented later.

**Sketch of physical changes.** The rocks of the Adirondack region are among the oldest of which we have knowledge anywhere on the earth's surface. The history which they disclose is an exceedingly difficult one to decipher and has been only imperfectly made out as yet. It is however clear that it involves the passage of a prodigious lapse of time.

The oldest known rocks of the Adirondack region are of the sort deposited from water, and indicate that the region, probably in its entirety, was below sea level and receiving deposit on its surface. These deposits would seem to have been of the same, or very similar, sort as those now being deposited on shallow sea floors: sands, muds, calcareous muds and their intermediate gradations. These rocks were apparently deposited in great thickness, though we have no means at present of ascertaining what that thickness was. They must have accumulated on a floor of older rocks, but this older floor has not yet been certainly made out in the Adirondack region. It may or may not be present. Volcanic action seems to have been going on while these deposits were forming, or else occurred not long afterward.

After these conditions had persisted for a long time, the district was raised up out of the water, probably to considerable hight, accompanied by a certain amount of folding, fracturing and tilting of the rocks. The surface ceased to receive deposit, and instead was attacked by the weather, the surface deposits were disintegrated and decayed, this loosened material commenced to move down hill toward the sea, and the surface was thus pared away bit by bit and lowered. This action continued through long ages till many hundred, likely a few thousand, feet of rock had been thus patiently removed.

The region also was early the scene of vigorous igneous action. Whether this preceded, accompanied and perhaps caused, or followed its uplifting above sea level is not known; but enormous masses of molten rock invaded the region from beneath in a great series of intrusions. Whether any of this material ever reached the then existing surface, with manifestations of surface volcanic action, we do not know, likely never can know. But not improbably these masses may represent old reservoirs whence volcanic material ascended to the surface.

The old floor, on which the previous deposits had been laid down, was largely or wholly engulfed in the molten flood, as were the old deposits themselves to a large extent. These were invaded, broken up, and separated into disconnected patches by the eruptive rock, which then cooled and solidified far underground. There is a series of these igneous intrusions with varying composition. The heart of the Adirondacks felt the full force of this action. The present borders were more remote from it, the igneous rocks are less conspicuous there, and the old sediments occur in greater mass.

At some date after the igneous action had ceased, though probably commencing while it was still in progress, the rocks were subjected to strong compression, acting mainly from one side. The rocks were compressed, intricately folded, the sediments were made thoroughly crystalline, all traces of their original structures were obliterated, and a foliated structure was produced in them and in the igneous rocks as well.[1] The general process is known as metamorphism. Side pressures can not produce effects such as these in rocks near the surface, but only at considerable depth; and, since these rocks are now at the surface, it is argued that the rock covering under which they were buried at this early time has been slowly and laboriously removed by erosive processes during the long ages that have since elapsed. They were likely at a depth of at least from 3 to 5 miles below the surface at this time.

The region persisted above sea level for a long time, during which likely occasional movements of further uplift were in prog-

[1]Under the temperature conditions which prevail at considerable depth and specially if moisture is present, high pressure produces rearrangement of the rock particles, mainly through recrystallization. The minerals form newly, mainly along certain dominant planes, and thus give the rock a layered arrangement. In sedimentary rocks this may or may not correspond with the old bedding planes. This layered arrangement of the constituent minerals constitutes foliation. Often ready splitting may be produced along these planes because of the concentration of a mineral with good cleavage there.

ress. As the surface was worn away, the present surface rocks were brought that amount nearer to the surface and were under the load of a constantly diminishing amount of overlying rock. From time to time renewed side pressures were brought to bear, these likely coinciding with times of renewed uplift and disturbance. But, as the rocks approached the surface in this slow fashion, the effects produced on them by the pressure would change in character. The pressure seems also to have been less pronounced than in the former stage and to have been mainly effective in producing joints.[1] Likely slipping and faulting also took place, but if so the faults have not yet been differentiated from those of a much later period.

Toward the close of this long erosion period, after much the larger part of the overlying rocks had been worn away, volcanic activity was renewed in the Adirondack region. The main center of the activity of this period was in the northeastern Adirondacks, and igneous rocks of this period make but little show in the south. They used mainly an eastwest set of joint planes for their ascent. We do not know whether any of this material reached the surface or not. If so, all traces of the surface materials have been since worn away. Nor has erosion anywhere cut deeply enough to disclose the old reservoirs whence these lavas arose, though they were the same in all probability as those whence came the material for the earlier great intrusions. We find exposed at the surface of today merely the old, lava-filled fissures which served as the channels of ascent for the molten rock. The surface outflows have disappeared through erosion and the original reservoirs are still buried in depth.

These rocks are known to be distinctly later than the other igneous rocks by various sorts of evidence. The dikes (the filled fissures) of the later rocks cut through the earlier. The later rocks are not metamorphosed as are the earlier. They have suf-

[1]Joints are divisional planes, usually vertical or highly inclined, found in most rocks. There are in general at least two sets of planes nearly at right angles. There may be several sets. They result from both tension and from compression, and are only formed comparatively near the surface.

fered deformation only to the extent of being jointed and faulted. Except for recent mere surface decay they are practically as when they cooled and solidified. They have therefore never been deeply buried, as have the rocks which they cut, but, on the contrary, seem to have formed not far from the surface, since some of them contain numerous gas cavities. Hence the larger part of the early erosion of the region must have been effected before their appearance and yet after the intrusion of the earlier eruptives.

The region was yet a land area at the time and so continued for a space. The result of the long protracted erosion of the surface was to wear down the old mountains to mere stumps, producing a region of comparatively low altitude and quite insignificant relief. There were stream valleys with low divides between and numerous low, rounded hills, whose tops were apparently no more than a few hundred feet above the valley bottoms as a maximum.

This old land area was of much greater extent than the present Adirondack region, though that was apparently a more elevated part of the surface then, as now, of less relief however and lower altitude. While the last, finishing erosion touches were being given to the present Adirondack region, the sea had already begun to encroach on its borders, either because of a sinking of the land area or a rising of the sea level. This movement persisted also for a long time, and the region seems to have become an island in the midst of the sea, of constantly shrinking area as the waters rose around it, till finally they seem to have overtopped it, completely submerging the whole. It is possible that a small area may have persisted above sea level throughout, though, it is not likely, and in any case it was very small.

As each successive zone of the district passed beneath the sea, it ceased to suffer wear on its surface and began to receive deposit instead. The last portion of the present Adirondack region to pass beneath the sea would seem to have been the southern part. Since subsidence and deposition were proceeding at the same time, each new layer of deposit would encroach a little farther on the old land surface than the preceding one. In other words, they overlapped on its slopes. The subsidence of this old land area seems to have been unequal on different sides, and also to have varied locally from place to place. Around most of the Adirondack region the first deposit laid down on the subsiding floor was one of coarse sand, often becoming a coarse gravel and with much feldspar sand at the base. It was deposited in shallow water in which was sufficiently strong current action to remove all fine mud. This formation is thickest on the northeast border of the

IDEAL SECTIONS ILLUSTRATING OVERLAP ON A SINKING LAND SURFACE, WITH MUCH EXAGGERATED VERTICAL SCALE


Fig. 1 Partial submergence; sand being deposited


Fig. 2 More complete submergence; limestone being deposited above the sand and also on the newly sunken land surface


Fig. 3 Almost complete submergence; shale depositing on the limestone and overlapping on the old land surface; the material being derived from some adjoining land area and brought in by currents.

Adirondacks, thinning thence both westward and to the south, and on the present southwest border was not deposited at all, and is not found within the map limits. The formation which succeeds it elsewhere is here found resting on the old land surface. A more detailed discussion of the reason for its absence here will appear on a later page. This formation is known as the Potsdam sandstone.

Subsidence continuing, the character of the deposit changed and the Potsdam is overlain by a variable thickness of dolomite and limestone beds, the former much predominating and nearly always containing some coarse sand which becomes very prominent in some layers. These rocks are peculiar, are not like ordinary open sea deposits, and the exact conditions under which they accumulated are not thoroughly understood. The formation is called the Beekmantown limestone, but was known as the Calciferous formation till recently. It is also thickest in the northeastern Adirondacks and diminishes in thickness to the south and west, so that near the region under immediate consideration it also disappears and the next succeeding formation is found resting on the old land surface. Within the limits of the map the different layers of the Beekmantown formation successively overlap on the old surface, so that a thickness of over 400 feet at Little Falls has diminished to nearly or quite zero at the northern limit of the sheet. The overlap is beautifully shown around Diamond hill, a low mound of the old land surface, and will be later described in detail.

Following the Beekmantown, a marine, fossiliferous limestone, the Trenton formation, was deposited, with two thin lower members, the Lowville (Birdseye) and Black River limestones. This formation was very unequally deposited and shows a very rapid diminution in thickness toward the east in the restricted district under consideration. The Lowville is a pure, drab, thick bedded limestone in which calcite-filled tubes abound, and is the main quarry rock of the district. The Black River is a massive, black, brittle limestone usually, and is only here and there present in the district, the Trenton usually following the Lowville directly. The Trenton is thin bedded and usually gray, though with some black layers, and many of the beds are a mass of fossil shells.

Toward the close of the Trenton, fine muds began to be washed into the previously clear sea, at first intermittently, producing a series of alternating limestone and shale bands, later more continuously, giving rise to the fine muds of the Utica formation. The abundant clear water life departed and was replaced by a different and much sparser assemblage of forms. During the deposition of this formation it seems probable, from several lines of evidence, that the present Adirondack region was either wholly submerged or else so nearly so that only a few small islands were left protuding above the water. Here again the deposit seems to have been thickest on the northeast, though the discrepancy is not so marked as in the case of the Potsdam and Beekmantown formations.

Following the deposition of the Utica formation, came a movement of disturbance and uplift of the region on the northeast and east. This apparently raised the present Champlain valley and northern Adirondack region above sea level, while the southern portion was not affected and remained submerged, so that the deposit of sediment continued on the south, though interrupted on the north. The successive Upper Silurian and Devonian rocks are now found outcropping in regular order as one goes south from the map limits, presenting their beveled edges to daylight. They all extended farther north originally. It would seem very probable, nay almost certain, that the higher Silurian rocks were deposited over the map limits and have since been removed by erosion. Quite possibly the Devonian also, in whole or in part, was so deposited.

There is a certain amount of evidence going to indicate that, during the late Silurian and early Devonian, the northern region became depressed again for a time and received deposit on its somewhat worn surface. But such deposit has been since wholly removed by erosion so far as northern New York is concerned, leaving us in entire ignorance as to its thickness, character and extent. Had these deposits been thick and of wide extent, however, we might reasonably hope to find remnants of them today, here and there. There is no evidence whatever that any rocks of later age than the Devonian have ever been deposited in, or about the Adirondack region, the recent Champlain clays and sands being of course excepted, and the evidence for the deposit of any of the Devonian is of the scantiest sort.

Probably coincident with the Taconic disturbance at the close of the Lower Silurian, occurred the last manifestation of igneous activity in the Adirondack region. This was mainly confined to the near vicinity of Lake Champlain, at least so far as the New York side is concerned. The igneous rocks of this date are now found in dikes, and occasional somewhat larger intrusive masses, which cut and are therefore younger than all the rocks of the region, up to and including the Utica formation. Their date can not be fixed more definitely than this.

On the south also there is evidence of igneous action of later date than the deposition of the Utica formation. A few dikes are found cutting this and the older rocks as well, which may or may not be of the same age as those of the Champlain valley. They are of a somewhat different sort of rock from any found there, and this may possibly argue for a difference in age. None of these dikes have been noted within the map limits, but three outcrop along East Canada creek just east of those limits. In character they show a closer relationship with some igneous rocks

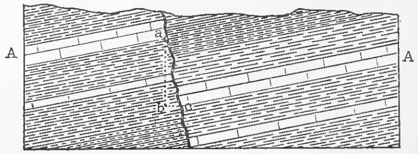


Figure 4

of apparent post-Devonian age which occur sparsely in central New York and they are probably related to them, rather than to the Champlain dikes.

Since the deposition of the Potsdam, Beekmantown, Trenton and Utica formations, the region has also suffered deformation, which has affected them as well as the older rocks. This later deformation has not been severe however. The rocks are but slightly folded, but are, on the other hand, considerably faulted and jointed.[1] This deformation period is of uncertain date except that it is later than the deposition of the rocks. Quite possibly

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[1]A fault is produced by a sliding movement of the rocks on opposite sides of a fissure, with the result that the same rock stratum is higher on one side than on the other, as illustrated in the accompanying diagram [fig. 4]. The stratum AA has been dropped on the right side of the fault relative to its position on the left side. The distance *ac*, measured along the fault plane, is called its *displacement*, the vertical distance *ab*, that separates the two ends of the stratum, is called the *throw*, and the horizontal distance *bc* is the *heave* of the fault.

the first faulting of the region took place at the close of the Lower Silurian coincidently with the Taconic disturbance. But, even so, a fault once formed constitutes a line of weakness, along which further faulting is likely to occur whenever the region experiences further disturbance. It is by no means unlikely that repeated slips have taken place along the fault planes since they were first formed.

Two such faults, the Little Falls and the Dolgeville faults, are found within the limits of the map, and thence eastwardly faults cross the Mohawk valley repeatedly. The Little Falls break is the most westerly one which has been detected in the State so far as the writer is aware, though it is not at all unlikely that small ones, at least, will be brought to light farther west. The Little Falls fault has a throw of nearly or quite 800 feet at Little Falls, and is hence of very respectable magnitude. There is another fault on lower East Canada creek, just beyond the map limits to the east.

The Little Falls district has been nearly or quite continuously above sea level for a long time; since Devonian time in all probability and likely during a part of the Devonian also. The length of this period of time in years can be measured by no one with any degree of exactness, but a few million years are involved beyond any question, and quite likely a good many million. During this time its surface has been undergoing wear instead of receiving deposit. A considerable thickness of the rocks which mantled the surface as it rose above the sea has since disappeared, and the present surface rocks are such because of the removal of what originally lay above. Undoubtedly the shales of the Utica formation once covered the entire area. They have now disappeared from more than half of it. The Trenton has also been worn away from much of the surface, so has the Beekmantown, and the old floor of all these rocks has been eaten away somewhat in the localities where it is now exposed at the surface. Such later formations as may have been deposited have been wholly removed. We can imagine them as replaced in their old position, since we know their order and thickness from their outcrops to the south, but we do not know at just what point to put the curb on our imagination.

The manner of progress of the wear on this land surface has depended on the rock characters and structures and must be left for later consideration. During this long time interval, the region has experienced changes of altitude, in part because of wear, in part because of up or down movements of the earth's crust. We are as yet far from being able to trace out these movements.

In times very recent comparatively, namely only some thousands of years ago, the district was covered by the ice sheet of the Glacial period. How long this condition persisted, how many times the ice came and went over the immediate region, we do not know. The advancing ice sheet removed the soil and loose rock from the surface and scoured away at the rock ledges beneath. The retreating ice sheet spread a heavy mantle of deposit over the surface. The melting ice gave rise to streams and lakes which rehandled some of the glacially deposited material. The larger preglacial topographic features were little changed and remain today substantially as they were before the onset of the ice. The minor irregularities of the surface were largely obliterated however, mainly by the deposits laid down during retreat. The stream valleys were filled nearly or quite to the brim, and the modern streams are largely in new courses therefore, specially the smaller ones. Unequal valley filling, and unequal deposit elsewhere left hollows in the surface in which lakes now nestle, lakes which had no existence before the advent of the ice. The Mohawk valley lowland is a preglacial feature, but the preglacial divide between the east and west flowing streams in this lowland seems to have been at Little Falls, and was certainly not at Rome, its present position. After the ice, on its last northerly retreat, had uncovered the Mohawk valley but still lay across that of the St Lawrence, the drainage of the Great lakes passed to the sea by way of the Mohawk, the eastern end of the lake in the Ontario basin being at Rome. The present Mohawk is an insignificant stream as compared with its great predecessor, which has of course left its mark on the valley.

The time since the departure of the ice has been so comparatively short, that the surface is substantially as the retreating glacier left it. During the retreat of the ice a slow movement of uplift was in progress in the region, and continued thereafter; in fact there are strong reasons for the belief that it even yet continues. Because of this change the Little Falls region stands today at an elevation exceeding by from 250 to 300 feet what it had when the last ice lay on it.

The streams of the region have either reexcavated their old valleys or are engaged in cutting new ones, but the time is not sufficiently long to have enabled them to make great progress in the latter task. Besides, the recent rising movement of the region has constantly lowered the level to which the streams can cut. Even the Mohawk is not down to base level at Little Falls and elsewhere. Away from the streams the glacial topography has been but little changed.

## THE ROCKS

### Pre-Cambrian rocks[1]

These ancient rocks are found at the surface over a large area occupying the northeast portion of the map, extending thence northward without a break through the entire Adirondack region. In addition, they appear at three disconnected localities, at Little Falls, Middleville, and at a spot locally known as the "Gulf," 2½ miles northeast of Little Falls.

**The Little Falls and Middleville outliers.** The pre-Cambrian rocks exposed at these two localities are identical, are quite homogeneous throughout, and are somewhat different in character from those exposed elsewhere. They are quite certainly old igneous rocks and belong to the syenite family of these rocks. They consist mainly of feldspar, always show some quartz, usually from 5% to 15% of the rock in quantity, and usually have only a small content of dark colored minerals, magnetite, hornblende, pyroxene and black mica. These minerals form a granu-

[1] A more detailed and technical description of these rocks will be given in the closing pages of this report.

lar mosaic in which are set feldspar crystals of varying size, whose glittering cleavage faces, on freshly broken surfaces, form the most noticeable characteristic of the rock. At Middleville these are very abundant and large, often reaching an inch and more in length, and the rock is much the coarsest syenite that has been found anywhere in the Adirondack region. In fact, it very strongly resembles in appearance much of the igneous rock called anorthosite, which has wide extent in the eastern Adirondacks. Both are composed mainly of feldspar, but the feldspar is of widely different character in the two. That of the anorthosite is apt to show striations, looking like fine ruled, parallel scratches, on the bright cleavage faces, but such striations do not appear on the syenite feldspar. The two differ much in chemical composition also.

The syenite at Little Falls is more widely and much better exposed than at Middleville, is by no means so coarse, varies more in character from place to place, and in part shows no large feldspars whatever. As shown along the Little Falls and Dolgeville Railroad, it was described in a previous report to the state geologist.[1] South of the Mohawk it is more homogeneous and more usually porphyritic than on the north side.[2] The westerly exposures, in and about the city, show considerable red, fine grained, granitic rock cutting the syenite.

This syenite has undergone extensive metamorphism, so that it has been rendered thoroughly gneissoid, and the finer grained portion of the original rock has been mostly, or wholly, recrystallized. The large feldspars also have been diminished in size by the breaking away of fragments from their exteriors. In general the Little Falls rock is much finer grained and vastly more gneissoid than that at Middleville. In places at Little Falls the large feldspars themselves have been completely crushed to a mass of fragments, and drawn out into lens-shaped patches, around which the foliation curves, as it does also around the uncrushed, large feldspars.

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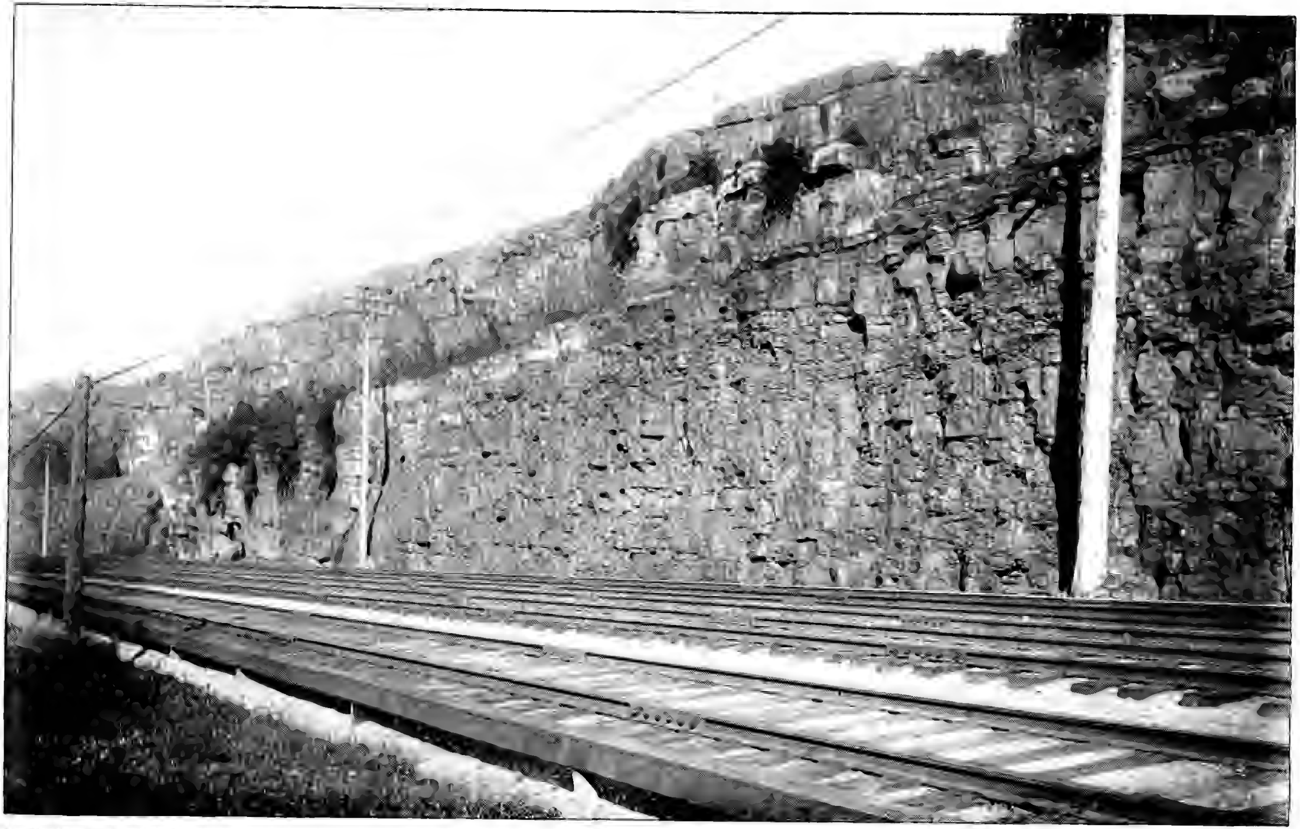
[1] N. Y. State Mus. 20th An. Rep't, p.r83.

[2] A porphyritic igneous rock is one which shows more or less numerous crystals, surrounded by more finely crystalline, or even stony or glassy rock material.



C. S. Prosser, photo

View of the cliff of pre-Cambrian syenite at Little Falls, looking west

Since these are small outliers and consist practically wholly of syenite, they can furnish no decisive evidence of the age of the syenite as compared with that of the other pre-Cambrian rocks. It has been stated that the Grenville rocks are closely involved with apparent igneous rocks which seem to have been either contemporaneous with them or to have been intruded into them not long after their deposition. Also that at a later date there was a time of great igneous activity in the region, when huge masses of molten rock were intruded into the Grenville rocks; and that at a third and much later time there was a further renewal of igneous activity, though in a minor degree. The writer's disposition is to regard the syenite under discussion as dating from the second of these periods, and as of much the same age as the the great syenite, anorthosite and gabbro masses of the central and eastern Adirondack region, but it should be emphasized that there is no decisive evidence in proof of this view. These two small areas are likely connected underneath and represent portions of the surface of the same mass, and it certainly represents a different intrusion from those in the heart of the woods, though regarded as belonging to the same group of intrusions.

*Diabase dike.* The only representative of the third igneous period which has been discovered within the map limits, is a huge dike of the rock known as diabase, which is exposed about a half mile east of the Little Falls depot along the Dolgeville Railroad. The rock is black and fine grained, with many half inch, porphyritic feldspars, of a general greenish gray, dull appearance because of alteration. Near the edges of the dike the rock becomes very black and dense and of stony texture, because of more rapid cooling and solidification there, due to the chilling effect of the walls. The dike is at least 120 feet in width, an unusually large size for these Adirondack dikes.

**Grenville rocks.** In the main pre-Cambrian exposures within the map limits, rocks which are of apparent sedimentary origin, and hence classed as of Grenville age, play an important part. The extreme metamorphism which they have suffered has produced complete recrystallization, with consequent disappearance of all traces of the original structures which characterize the sedimentary rocks. The argument for their sedimentary origin rests on their composition, mineralogic and chemical, and on their frequent variations in composition, beds of different original character having produced differing metamorphic rocks, whose comparatively sharp junctions look like old bedding planes.

The most characteristic rocks of the Grenville series are the crystalline limestones, but these have not been found within the map limits. A single large boulder of impure crystalline limestone was noted on the surface of the heavy moraine which covers the district occupying the extreme north-central part of the map. As it is a soft and quite easily destroyed rock, these limestone boulders commonly indicate a parent ledge near at hand, here probably to the north, not far beyond the map limits.

In the absence of limestone, the rocks regarded as characteristically Grenville comprise a series of light colored, often white gneisses, very rich in quartz, interbanded with less quartzose rocks of darker color, and often with a very respectable percentage of black minerals, hornblende, black mica and magnetite. Both rocks contain, often in abundance, garnets of somewhat unusual color, a much lighter red than ordinary and with a rather pink tinge. These are more conspicuous in the dark rocks in general, but the light colored ones are seldom without them. They are commonly of about pinhead size but often run larger, specially in the darker rocks, those with diameters of from ⅛ to ¼ inch being often quite numerous, and even larger ones are to be found.

Another mineral which is very characteristic of these rocks and strongly indicative of their sedimentary origin, is graphite (black lead). Shining, metallic looking scales of this mineral occur frequently in the darker rocks, usually of sufficient size to be made out by the unaided eye.

Another characteristic mineral, this time confined mainly to the light colored rocks and only visible under the microscope, is sillimanite.

As has been said, the light colored rocks consist almost wholly of quartz and feldspar and are rich in quartz. Their composition would indicate that originally they were sandstones, generally more or less shaly. In many of them the quartz is now found in thin, regular leaves separated by very finely granular feldspar, and such "leaf gneisses," as Dr F. D. Adams of the Canadian Survey has happily styled them, are a very conspicuous feature of the Grenville rocks. However, the severe metamorphism to which most of the pre-Cambrian rocks have been subjected has recrystalized much of their quartz in the leaf form, both in those of igneous as well as in those of sedimentary origin, so that this character can not be regarded as in any sense indicative of origin. It is naturally best exhibited by rocks rich in quartz, and some rocks which were likely granites originally show it in great perfection.

The darker colored rocks would seem to have been shales and calcareous shales originally. They must have contained a small amount of carbonaceous matter, very possibly of organic origin, now metamorphosed to graphite. Many ordinary shales and limestones contain carbonaceous matter, so that the supposition is a very natural one.

These Grenville rocks are very like rocks which Kemp has recently described from Warren and Washington counties, to the eastward, where they also occur in abundance, and where limestone is relatively scarce. From the standpoint of one who is familiar with but one of the two districts and necessarily depending on descriptions for a knowledge of the other, the rocks would seem identical in the two areas, and not unlikely the whole pre-Cambrian fringe on the south side of the Adirondacks will be found to be characterized by abundant Grenville rocks with a scarcity of limestone.

**Probable igneous rocks associated with the Grenville.** At most of the Grenville exposures of any extent, rocks which are regarded as igneous are found mingled with them. They are always thoroughly gneissoid and are interbanded with the old sediments. They are thought to represent old dikes and sheets of igneous rock, possibly surface flows also, which were formed during, or not long after the deposition of the sediments, and which have been recrystallized and stretched out into rude parallelism with the sedimentary beds as a result of severe metamorphism.

Though of somewhat variable nature, they present three main types:

1 Red gneisses which have the mineralogy of granites, and are thought to have corresponding chemical composition also, though they have not been analyzed. They are usually fine grained and with quartz of a pronounced leaf type.

2 Black, hornblende gneisses, sometimes with pyroxene also and usually with black mica (biotite), which have the composition of gabbros or diabases.

3 Greenish gray gneisses, which have somewhat the color and appearance of very gneissoid varieties of the syenite previously described, and are very difficult to distinguish from them when occurring alone. They are commonly very quartzose, more so than the usual syenite, and very distinctly of the "leaf gneiss" type. They are very like the red gneisses of the first type under the microscope, have the mineralogy of granites, or of quartz syenites, and are regarded as igneous rocks. Their possible relationship with the Little Falls syenite is an exceedingly difficult problem, not as yet satisfactorily solved, though they are hesitatingly regarded as distinct and as older.

Though all these rocks are usually found interbanded with the Grenville sediments, so that there can be little doubt as to their close association, they may occur elsewhere unaccompanied by the sedimentaries, or with these in very minor quantity, and such areas have been given a separate coloration on the map, though the distinction is not a sharp one, and there is some question as to its wisdom.

**Syenite gneiss.** There is a considerable area shown in the northeastern part of the map where the rock is of the same sort throughout. The exposures are all in the woods and of the unsatisfactory sort that obtain there. The rock is thoroughly gneissoid, of a greenish color and weathers rapidly to a dingy brown. Most of the exposures show nothing but the brown rock, though usually freshly broken surfaces will show at least patches of the green. The grain is usually quite fine, but the quartz is coarser than the other constituents and tends often to the "leaf" type, though but rudely so. In places a few larger feldspars show also and appear like small examples of porphyritic feldspars. The rock is prevailingly of feldspar, and feldspar of an acid type. It is quite quartzose, that mineral making from 15% to 20% of the rock on the average with a usual range of from 10% to 30%. Pyroxenes are the usual dark colored constituents, though both hornblende and biotite mica also occur. Without going into detail at this point suffice it to say that the rock has the precise mineralogy of an augite syenite, the same mineralogy as the rock at Little Falls and Middleville, and the same as the great mid-Adirondack syenite masses. It differs from them in being in general somewhat more quartzose, in being everywhere thoroughly gneissoid, and in the lack of porphyritic feldspars. It is however not to be in any way distinguished from some varieties of the rock in the other exposures. On the other hand, it has nearly, if not quite, as strong a resemblance to the greenish gneisses (3) just previously described.

**Mixed rocks about the syenite.** A large part of the pre-Cambrian area of the sheet shows rocks which are very like the syenite rocks and are thought to represent phases of them, but which are inextricably intermingled with smaller masses of undoubted Grenville rocks. The syenitic rocks predominate, though they are not of the normal type, but the Grenville rocks are in considerable force, and the relations between the two are wholly obscure. It was found impossible to separate the two in mapping on this scale, and therefore the complex as a whole is given a separate coloration on the map. Since the rocks seem to pass into the syenites on the one hand, and into belts in which the Grenville sediments preponderate on the other, the mapping of boundaries must, however, be a wholly arbitrary matter.

A very mixed lot of rocks is found in this belt as mapped, and with frequent changes from one sort to another. The most abundant type of all is a greenish gneiss, weathering brown.

which is richer in biotite, hornblende and pyroxene than the usual syenite. Metamorphism has concentrated these minerals along certain planes, producing a marked gneissoid structure, and a rock varying from green to black in general color. Where thus enriched by these minerals the rock approaches more nearly to a gabbro in composition, otherwise it is a syenite, though often very quartzose. With the increase in the quartz percentage the color often changes with facility from green to red and back again, just such a color change as is often seen in the great Adirondack masses of syenite. Bands of very basic feldspar, hornblende, biotite gneisses occur frequently with the others, and the whole series is cut by a multitude of small veins of quartz and pegmatite. Rocks like these appear in a multitude of exposures. All have the mineralogy of igneous rocks and are believed to be such.

Along with these a rock repeatedly occurs which resembles somewhat the green and black gneiss of the above, but contains garnets numerously also. It has the mineralogy of a rather basic igneous rock, neither a gabbro nor a syenite however, but of a rock intermediate between them and known as monzonite. It passes on the one hand into the syenite gneisses and on the other into the darker colored gneisses, often with graphite, of the Grenville series, the lighter colored gneisses appearing with these at times also. The whole series is perplexing and uncertain. The rocks differ considerably from the red, black and green gneisses previously described and regarded as igneous rocks of Grenville age. A possible, and perhaps the simplest explanation of the whole is that it is a sort of border belt between the syenite and the Grenville rocks, in which these last were all cut up by the syenite intrusion and in which they now occur as patches. Many contact rocks were formed and the whole subsequently was severely metamorphosed.

There still remains the question of the relationship of this syenite to that at Little Falls and Middleville, and to it the writer is unable to give any definite answer. If they are equivalent, it is strange that the pronounced porphyritic character of the rock of the two outliers should have so utterly disappeared in the main mass. Yet it may be legitimately argued that the porphyritic texture is usually of local development in deep seated igneous rocks, that much of the rock at Little Falls lacks it and is thoroughly gneissoid, hence presenting an intermediate stage between the rock at Middleville and that of the main mass, and that in the great syenite masses of the central Adirondacks the bulk of the rock is not porphyritic, and the porphyritic development is local; also these are, at least in part, demonstrably of considerably younger age than the Grenville rocks.

Moreover, as has been stated, this syenite is almost equally hard to distinguish from the greenish gneiss of syenitic composition found so closely associated with the Grenville sedimentaries, and the granitic and gabbroic gneisses that accompany them. While this greenish gneiss is regarded as an igneous rock, it seems quite certain that its age association with the sedimentaries is close, as is also that of the accompanying granitic and gabbroic gneiss. It is also true of these latter that they are certainly much older than the gabbros and some granites which occur in the mid-Adirondack region, and it would seem therefore that the same might well be true of the syenite also. The green gneiss is regarded as being of this earlier age, so that there seem to be syenite rocks of at least two different ages in the Adirondack pre-Cambrian. But the writer is in doubt with regard to the syenite mass of the northeast part of the map, though disposed to regard it provisionally as belonging to the earlier period and to correlate it with the green gneisses of the Grenville. In regard to the rock at Little Falls and Middleville, he is also in doubt, though here with a disposition to refer to the later period, and to correlate with the later syenite of the central Adirondack region. The whole matter is one of great difficulty, and no decisive evidence for either view has yet been forthcoming anywhere.

**Pre-Cambrian outlier northeast of Little Falls.** There is exposed here a gray gneiss with a slight greenish tinge. The exposure is very small and shows but the one sort of rock. It is in the main a quartz feldspar rock, not more than 5% of other minerals being present, mostly magnetite, biotite, and a decomposed mineral which was likely a pyroxene. Quartz makes some 20% of the rock.

From 20% to 25% of the feldspar is oligoclase and the remainder is anorthoclase. The composition is that of a rather acid quartz syenite, and the rock is provisionally classed with the green gneisses associated with the Grenville rocks.

## Paleozoic rocks

**Potsdam sandstone.** Though it has been sometimes held that this formation is present in a small way in the district, the writer found nothing that would warrant its mapping as a lithologic formation distinct from the Beekmantown. At the base the Beekmantown is often more sandy than usual and even pebbly, sometimes a thin shale band creeps in as at Little Falls, and sometimes a thin, disintegration conglomerate or breccia band, composed mainly of fragments of the underlying rock, is locally found. But these phenomena are precisely what would be expected, as an old land surface sank beneath sea level and began to receive deposit. These lower layers vary greatly in character from place to place, always are somewhat calcareous and usually are prevailingly so, and seem to have nothing in common with the coarse, pure quartz sands of the Potsdam formation. Furthermore, beds of this character are not confined to the base of the formation but equally sandy, sometimes pebbly, beds are found here and there at various horizons. Moreover, since the Beekmantown formation overlaps on the pre-Cambrian, the formation thins going north from the Mohawk, and hence successively higher and higher beds become basal. The small area near Salisbury, which Darton has mapped as Potsdam is, though basal, at an horizon at least 200 feet above the bottom of the formation as shown at Little Falls. The same characters run through several layers in the distinct overlap of the formation at Diamond hill, the ordinary character being resumed at a little distance from the spot, and the rock is still somewhat calcareous and has not the lithologic character of the Potsdam.[1] Nor does the basal bed at Little Falls appear to represent the real base of the formation, deep well records to the west seeming to indicate an increased thickness in that direction, under

[1] N. Y. State Geol. 14th An. Rep't 1894. Map at p.33.

cover of the younger rocks. These are at a greater distance from the pre-Cambrian outcrops than are the exposures at Little Falls, and this increased thickness is no doubt due to overlap, as is the diminished thickness in the other direction. It is therefore held that there is nothing which can be mapped as a formation, corresponding to the Potsdam, in this portion of the Mohawk valley, but that the Beekmantown rests everywhere on the pre-Cambrian, overlapping on its surface. It is by no means impossible that the Potsdam may come in below, farther away from the present pre-Cambrian edge of outcrop, but there is yet no decisive evidence that this is so.

It is also possible that the base of the Beekmantown, as exposed at Little Falls, may be of Cambrian age. This can only be determined by fossils, and as yet these have not been forthcoming in sufficient number and variety to settle the question.

**Beekmantown formation.**[1] The Beekmantown rocks are best exposed about Little Falls, Middleville and Diamond hill, though presenting numerous outcrops elsewhere. In the main, they consist of a gray, more or less sandy dolomite. Occasional layers are very sandy and sometimes even pebbly, and such layers are not confined to the base but may appear at any horizon. Some sandy layers show bright, glittering cleavage faces when broken. Such layers are found in the formation all about the Adirondack region,

[1]The paleozoic rocks of the Mohawk valley have been much studied and described, and the writer's work has added little to our knowledge of them except for some structural details. The main purpose of the work was the study of the pre-Cambrian rocks; and, since the prosecution of this work required considerable traversing of the rest of the area, it seemed a pity not to grasp the opportunity to delimit all formation boundaries on the accurate base of the recently published new map. The more important papers touching on the stratigraphy of the immediate district are as follows:

**Clarke, J. M.** U. S. N. Y. Handbook 15. p.60-63
**Darton, N. H.** N. Y. State Geol. 13th An. Rep't. 1893. 1:409-29
——— N. Y. State Geol. 14th An. Rep't. 1894. p.33-53
**Hall, James.** N. Y. State Geol. 5th An. Rep't. 1885. p.8-10
**Prosser, C. S.** Am. Geol. 25:131-62
——— N. Y. State Mus. Bul. 34, p.469-70
**Prosser & Cumings.** N. Y. State Geol. 15th An. Rep't. 1895. p.632-37
**Vanuxem, L.** Geol. N. Y. 3d Dist. 1842.

and the writer has elsewhere shown that the appearance is due to a secondary calcite cement deposited between the sand grains, so that they become as it were incorporated in calcite crystals whose cleavage gives the characteristic appearance to the broken rocks.[1]

Many of the beds of the formation, in the Little Falls district, are full of small, drusy cavities which are in general coated with minute dolomite crystals, sometimes with calcite as well. In these cavities are often one or more quartz crystals, generally small and water clear, though sometimes of quite large size, the latter usually full of inclusions. These crystals have long been known and have made the district a famous one to the mineralogist. They are locally known as diamonds and have given the name to Diamond hill, where they are very abundant, as they are also about Middleville. In addition, the cavities often contain much of a black, carbonaceous material, sometimes nearly filling the cavity, sometimes as films on which the dolomite crystals rest, sometimes running into cracks of the rock, and sometimes occurring as inclusions in the quartz crystals in a finely divided state. This material has heretofore been called anthracite, behaves precisely like that substance when heated and must have the same approximate chemical composition, though with somewhat different physical properties. From the standpoint of origin it would seem to be certainly an asphalt derivative. It was the first substance to form in the drusy cavities and was followed by the dolomite crystallization, though the two seem to have overlapped somewhat. Both the quartz and the calcite were formed after the dolomite. The writer observed no instance of a cavity in which quartz and calcite were both present; so that it can not be stated which of the two was formed first.

Near or at the summit of the Beekmantown formation, is a very cherty layer, becoming locally a pure mass of chert, which is sometimes red in color. This cherty layer often has a mineralized appearance, due to abundant, small, bluish green spots which have some resemblance to green copper carbonate (malachite).

[1] N. Y. State Geol. 16th An. Rep't. 1896. p.19.

C. S. Prosser, photo.

The Beekmantown formation at Little Falls. Boyer quarry in sandy dolomite, forming the basal portion of the formation; a shale band shows at the base, and the pre-Cambrian lies just beneath.

There is however no copper at all in the rock and the green spots appear to be constituted of glauconite.[1]

A certain amount of mineralization is sometimes to be noted in some of the layers of the formation, zinc blende (sphalerite), galena, pyrite and chalcopyrite all occurring, though always in small quantity.

The Beekmantown formation is overlain by a pure gray limestone known as the Lowville. The Chazy limestone lies at this horizon along Lake Champlain, but does not appear in the Mohawk valley. Its absence is due to a cessation of deposition in the Mohawk region and an uplift which probably raised the district slightly above sea level, sufficiently to stop deposition, but not sufficiently to permit of much wear. This uplift likely involved all of the State except the Champlain region, and persisted through the latter part of Beekmantown time and throughout the Chazy. Then subsidence was renewed, though but slowly at first.[2]

In the Little Falls district the upper boundary of the Beekmantown is not everywhere sharp, a grading into the Lowville through a series of passage beds of intermediate character being often seen, as was first noted by Prosser.[3] These beds are of no great thickness, 8 feet being the maximum noted by the writer, along White creek nearly 3 miles north of Middleville. Prosser measured 11 feet at Newport on West Canada creek not far west of the map limits. These beds are of too slight thickness and too interrupted to map separately on a map of this scale, and have been therefore included with the Beekmantown, the base of the Lowville being made at the first pure limestone stratum.

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[1] Glauconite is a mineral of varying composition, but essentially a silicate of iron and potash. In sedimentary formations it has often a close association with the skeletons of minute organisms; and, since the chert is likely of organic origin, the association is a natural one. It is not at all indicative of any mineral content of value in the bed.

[2] The Chazy formation is over 800 feet thick toward the lower end of Lake Champlain, and diminishes rapidly in thickness to the south and west till it wholly pinches out. Moreover the entire Lower Paleozoic rock series is thickest on the northeast, diminishing thence west and south, so that more profound subsidence appears to have characterized the former region throughout.

[3] N. Y. State Geol. 15th An. Rept. 1895. p.627-31.

Just east of Middleville the upper layer of the Beekmantown is a coarse conglomerate, consisting of pebbles of quartz and chert in a matrix of quartz sand grains, cemented by calcite. This conglomerate was noted at but the one locality, but elsewhere a very sandy, sometimes slightly pebbly, layer, often full of pyrite (marcasite) is seen at this horizon, instead of the usual chert layer.

The best exposures of the Beekmantown are those at Little Falls, where, on the south side of the river, nearly every foot of the 450 feet thickness of the formation may be seen. The exposures about Middleville are also very good, though the thickness has dwindled to about 200 feet, and a section so nearly continuous can not be seen. The contact on the pre-Cambrian is shown in the West Shore railroad cut at Little Falls, and also in the banks of Spruce creek at Diamond hill [see pl.3]. It formerly showed, in the Boyer quarry at Little Falls, and even yet almost does so. All along the line of contact on both sides of the river at Little Falls the contact just escapes showing.

The Spruce creek locality has been noted by both Vanuxem and Darton.[1] The pre-Cambrian rocks there are garnetiferous Grenville gneisses with quartz veins, with some basic layers, and some rusty weathering beds full of pyrite. One of the latter is at the contact for the slight length of its exposure, and plate 3 illustrates its rapidity of weathering as compared with the overlying Beekmantown. The more resistant quartz veins project into the overlying Beekmantown layer, so that specimens of almost solid quartz can be broken out from it. Otherwise it, and the next two layers, have an arkose character, and the lower of the two is quite pebbly. They are also full of pyrite locally. While their materials are somewhat waterworn they consist merely of more or less weathered fragments of the underlying rocks, the resulting rock being mainly a product of weathering rather than of sedimentation. But these beds grade rapidly into the ordinary Beekmantown above, are themselves somewhat calcareous, and make a perfectly logical basal layer for the formation. In plate

[1]Geol. N. Y. 3d Dist. p.255.
N. Y. State Geol. 13th An. Rep't 1893. p.417.

H. P. Cushing, photo.

Contact of Beekmantown on pre-Cambrian in Spruce creek at Diamond hill. The upper pre-Cambrian decays readily, and the actual contact is visible for only a few feet and can not be clearly brought out in a photograph. The pre-Cambrian shows best at the right.

N. H. Darton, photo.

Beekmantown-pre-Cambrian contact in West Shore Railroad cut at Little Falls. The plate shows the pebbly character of the lower Beekmantown layer, but this is a not infrequent character in the district. The pre-Cambrian is augite syenite.

4 the contact on the south side of the river at Little Falls is excellently shown. The lower layer is quite pebbly and extra sandy, as it is at Spruce creek, but the basal layer at Spruce creek, because of overlap, is from 150 to 200 feet above this pebbly layer at Little Falls. It is unlikely that this latter represents the actual base of the formation and a reference to the Potsdam because of lithologic character seems wholly uncalled for in view of the above facts.

The contact with the overlying Lowville limestone is shown at numerous localities within the map limits, and at many others shows within a few feet. A number of the tributary creeks into West Canada creek, both above and below Middleville, expose this contact. Some of the creeks into the Mohawk from the south also expose it, and it is well shown about Ingham Mills. A comparison of these different contacts brings out some interesting things in regard to the presence or absence of the passage beds, and variations in thickness of the Lowville down to complete absence, going to show great local variation in deposition conditions at this horizon, and indicating, when coupled with the occurrence of the local conglomerate at the summit of the Beekmantown, a probable slight unconformity.

**Trenton formation.** The Trenton formation as mapped is made to include the Lowville and Black river limestone stages as well as the Trenton limestone, since in the district these are mainly too thin and too variable to be mapped separately from the Trenton without exaggeration. They lie below the Trenton and can in general be assumed to represent the basal 5 to 15 feet of that formation as mapped.

*Lowville limestone.* The different beds of this formation are very similar, consisting of gray, brittle, pure limestone layers in which are more or less numerous long, tubular cavities filled with white, crystalline calcite, which are exceedingly characteristic of the formation. Other fossils are very rare, though Leperditia, a fossil crustacean shell looking like the half of a small bean, occurs occasionally. It is the purest limestone in the district, is fairly thick bedded, and has therefore been considerably quarried for building stone for local use.

About Middleville the formation ranges from 15 to 21 feet in thickness, the 6 to 8 feet of passage beds being excluded. To the westward it is still thicker, as shown by Prosser about Newport. South from Middleville it quickly dwindles to an average thickness of about 10 feet, and this it keeps all along the Mohawk to the east limits of the map, ranging from 8 to 12 feet thick. About Ingham Mills, Prosser has measured one thickness of a little more than, and another of a little less than, 10 feet.

The upper boundary of the formation is commonly sharply defined, the overlying Black river or Trenton being of quite different character and passage beds being lacking. Occasionally a layer with the lithologic character of the Lowville recurs a few feet above the summit of the main formation, as has been shown by Prosser at Ingham Mills, but this is exceptional.

About Diamond hill and thence northward, the Lowville shows nowhere in outcrop, and in places the Beekmantown and Trenton occur sufficiently close together to show that, if the Lowville occurs here at all, it must be under 5 feet thick. In the Mohawk valley to the eastward, beyond the map limits, it disappears entirely for an interval.

*Black river limestone.* Normally this formation consists of thick bedded, black, brittle limestone which underlies the Trenton directly. In the Little Falls district it is mostly absent, the Trenton directly following the Lowville. So far as the writer is aware, Prosser was the first to show its presence in the district, he reporting the 5 foot thickness which is shown at Ingham Mills.[1] But just north of the mills, at the second bridge, the old quarry face shows 10 feet of Black river limestone, with the Lowville below and Trenton above, in a vertical 25 foot section [see pl.5]. It consists of 4 to 8 inch layers of black, brittle, blocky limestone separated by shale partings of approximately equal thickness. The limestone bands are like the Black river in lithologic character and in stratigraphic position, and contain fossils rather numerously, so that it will be easy for the paleontologist to determine whether or not it is the normal Black river fauna, as it seems to the writer to be.

[1] N. Y. State Mus. Bul. 34, p.469.

H. P. Cushing, photo.

Quarry face at bridge north of Ingham's Mills, showing 10 feet of Lowville (Birdseye) limestone at base, followed by 8 feet of thin black limestone bands with shale partings, of Black river age, and capped by 5 feet of Trenton limestone.

A thickness of 4 feet of black limestone with shale partings, quite like that at Ingham Mills, is exposed ½ mile to the southeast at the brook and road crossing near the east edge of the map. The Trenton appears directly above, but the full thickness and the Lowville below do not show.

Away from the vicinity of Ingham Mills the formation has been noted at but one locality within the map limits. By the road from Diamond hill to Gray, nearly 4 miles beyond, and slightly to the west of north of Diamond hill, the Lowville limestone is shown and capped by a 3 foot thickness of solid, black limestone with the Black river character and fauna. The summit does not show.

All the other contacts within the map limits, and they are many, show the Trenton resting directly on the Lowville, with the exception of one a mile north of Middleville, which discloses a thickness of 1 foot of black, calcareous shale between the two. We have therefore nearly as marked evidence of irregularity and interruption of deposition above the Lowville as there is below. There is to be added to this also as significant, the variation in thickness of the Lowville itself, and the fact that the nearly complete lack of a marine fauna in it would likely indicate local and restricted deposition conditions, rather than those of the open sea. The marine fauna would certainly have been preserved in the rock had it been there.

*Trenton limestone.* The larger part of the thickness of the Trenton within the map limits is constituted of a gray, thin bedded, semicrystalline limestone, often a mass of fossils or of fossil fragments, locally called shell rock. With this are layers of dark blue limestone, sometimes rather massive but oftener thin, and with a shaly tendency. These are sometimes very full of fossils also, but usually contain them much more sparingly than do the gray beds. In general the gray beds are more prominent in the lower, and the dark blue in the upper part of the formation.

Upward, the gray layers die out entirely, and the limestones are succeeded by a considerable thickness of alternate limestone and shale bands of blue black color, which form a lithologic transition zone between the Trenton limestone below and the Utica shale above. The limestone bands range from 3 to 18 inches in thickness, and the rock is hard and brittle and quite like the dark blue beds of the Trenton. The shale partings are of blue black shale quite like the Utica above. There is a diminution in amount of limestone and increase in that of shale upward, but on the whole a pretty constant and rapid alternation of the two, continuing through a vertical interval which varies from 25 to 100 feet in thickness, thickest on the west and thinnest on the east.

Lithologically these beds are no more Trenton than they are Utica but are distinctly intermediate in character, and no more to be classed with the one formation than with the other. There is some little shale in the Trenton below, and some rather calcareous beds in the Utica above, but not in sufficient quantity to characterize the formation in either case. Whether the contained fossil fauna would ally the transition beds more distinctly with the underlying or the overlying formation, the writer is not qualified to determine, though strongly of the opinion that the fauna is equally a transition one. Apparently these beds have been classed with the Utica heretofore.

Most of the limestone bands of these passage beds are fossiliferous only sparingly or not at all, but some contain fossils in considerable numbers, and search in the shales will nearly always bring them to light. In the basal portion are some very fossiliferous, black limestone bands which seem unmistakably Trenton.

The best exposures of the Trenton limestone within the map limits are shown in the brooks tributary to West Canada creek from Middleville south. Stony creek, coming in from the east at the county house, shows the best section, comprising the upper portion of the Beekmantown, the entire Lowville which is 15 feet thick here, followed by an unbroken section of 100 feet of Trenton. For ½ mile the fall of the creek is very rapid and most of the section is comprised within that limit. Above, the stream is flowing down the dip for the most part, and the rock thickness passed through in the remaining ¾ mile of exposures is not great. The section ends at or near the base of the passage beds, and above are no rock exposures for 2 miles, when Utica shale appears at an altitude 300 feet higher.

The two brooks which come down from the west, the one just above, and the other just below the county house, show the upper part of the section and the contact between the passage beds and the Utica, though their sections are much more interrupted by breaks than is that of Stony creek. The combined section of the three creeks shows a thickness of about 100 feet of Trenton and an equal thickness of the passage beds, or 200 feet in all between the Lowville and the Utica.

There are also most excellent Trenton exposures along East Canada creek, the best being just above Ingham Mills, where the full thickness is shown in a cliff face which is unfortunately most inaccessible even at low water, since the full volume of the stream hugs that bank. A mile farther up stream it again shows magnificently, being brought up by a low fold, but here the base is not reached and the summit is cut off by a fault which crosses the creek.[1] Up the little brook, above the Black river limestone locality already referred to southeast of Ingham Mills, an uninterrupted thickness of nearly or quite 40 feet of Trenton appears, overlying the Black river. The Trenton hereabouts is nearly or quite 50 feet thick, and the passage beds have a nearly equal thickness. This is somewhat less than half the thickness shown along West Canada creek, and the many exposures elsewhere indicate a progressive thinning of the formation eastward.

From 13 to 15 miles northwest from Middleville are the noted Trenton falls and gorge along West Canada creek. Here the Trenton has a measured thickness of 270 feet, with neither the base nor summit exposed, so that the true thickness is an unknown, but likely small amount in excess of that figure.[2] The same distance to the southeast from Ingham Mills, down the Mohawk at Canajoharie, the thickness has diminished to 17 feet, [plate 10], is lithologically rather like the rocks here classed as passage beds, and the lower part of the Utica seems to have some-

[1] Clarke, J. M. U. S. N. Y. Handbook 15, p.61.

[2] Prosser. N. Y. State Geol. 15th An. Rept. 1895, p.626.

what the same character.[1] So it is evident that the thinning of the Trenton eastward across the territory included in the map sheet, is only a local exhibition of a more widely extended feature.

**Ripple marks in the Trenton.** A mile above the mouth of the creek which empties into West Canada from the east 2 miles above Middleville is an interesting exhibition of ripple marks, interesting because of their comparative rarity in limestone formations. The Trenton section up this creek is a very interesting and complete one. The ripple-marked horizon is about 100 feet above the base of the Trenton and in slaty limestones which approach the passage beds in character. The stratum has a slight westerly dip and the creek flows down the dip for several rods, so that the rippled surface is widely exposed. The crests of the ripples are from 9 to 15 inches apart, so that they are considerably broader than the usual ripple marks in sandstones, and the troughs are depressed from 1 to 3 inches below the crests. They run nearly at right angles to the course of the stream, which is thus flowing down a gently inclined, corrugated surface. There results from this a number of little, local eddies in the water, which are strongest in the lowest sags of the troughs. Here the water is beaten up into foam, forming globular masses up to 6 inches in diameter, which rotate in the eddying water and give a very striking appearance to the stream. Varying dip brings this layer to daylight again some 50 rods farther up stream. Not far beneath is a knobby, black limestone layer, full of nodules of chert, containing much pyrite (marcasite), and holding a great number of specimens of a single species of fossil (Orthoceras).

**Utica shale.** This formation consists throughout of black, or blue black, somewhat carbonaceous, fine mud shale. It is mostly very thin splitting (or fissile), this being specially true above. In the lower portion more solid bands are not infrequent, and the shale is usually somewhat calcareous, thin bands of slaty limestone being of frequent occurrence in the basal portion, though

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[1] Prosser. *Op cit* p.638-40.

not constituting the marked feature of the formation that they do in the passage beds.

The overlying Lorraine shales of the Hudson group were not noted anywhere within the map limits, and it is thought that their horizon is nowhere reached. North of the Mohawk only the lower portion of the Utica is exposed, little beyond the lower 200 feet, if any. South of the river, much higher beds are found, and the altitude of the hills in Danube and German Flats at the south line of the map is nearly or quite sufficient to reach the Lorraine horizon. But these hills are heavily drift-covered, and so deeply so that the actual rock exposures beneath are at a horizon considerably below what the altitude of the hill summits would indicate. The highest beds actually seen are in the town of Danube and on the southern edge of the map. The black, slaty shales outcropping here are 500 feet in altitude above the base of the formation which, together with the upper layers of the passage beds, outcrops near Indian Castle. Since, in addition, the former are 2 miles west of the latter, and since the dips are low to the southwest, these beds must be somewhat over 500 feet above the base of the formation and are likely not far from its summit. The actual summit of the hill on the side of which this outcrop appears, is 200 feet higher, but it is a moraine knob on which the drift is so heavy that all rock is deeply buried beneath. The thickness of Utica shale shown in the Campbell well near Utica is given as 710 feet by Mr C. D. Walcott.[1] It may be thicker or thinner here but is certainly close to 600 feet, exclusive of the passage beds and with the summit not reached.

## STRUCTURAL GEOLOGY

### Dip

The Paleozoic rocks were originally deposited as nearly horizontal sheets, though with a probable slight inclination to the south or southwest. Oscillations of level in the region since that time have given the rocks a somewhat greater tilt in the same direction, the rocks have been slightly folded also, causing loca.

[1]Am. Ass'n Adv. Sci. Proc. 36:211-12.

variations from the general direction of dip, and they have also been faulted, producing again local variations, which are most marked near the fault lines.

The general direction of dip in the immediate district is to the southwest. The amount is variable though seldom exceeding 5°, and the general average is much less than this. The steeper southwest dips are counteracted by occasional changes of dip to the northwest, because of slight folding. The average dip can only be obtained by bringing large distances into consideration. For example, just east of Middleville the summit of the Beekmantown (the most convenient horizon for the purpose) lies at an altitude of 800 feet above sea level. In the deep well at Ilion, approximately 10 miles distant in a direction somewhat to the west of south, the same horizon was reached at a depth of 630 feet below the mouth of the well, or 225 feet below sea level, an altitude 1025 feet lower than at Middleville and amounting to a fall of somewhat over 100 feet to the mile. This represents a dip not greatly in excess of 1° in this direction. It is quite possible that this is not along the line of greatest dip, that running somewhat more to the westward, but it is exceedingly unlikely that the general dip exceeds 2°.

In the near vicinity of faults steep dips have often been produced by the drag of the rock masses on each side of the fault plane as they have moved past one another during the faulting, the layers being bent upward on the downthrow, and downward on the upthrow side of the fault. The less massive and rigid rocks are, the more they yield to this drag, and hence its effects are in general more pronounced on shales. The Utica shales have thus been given very steep dips near the fault lines of the district, being found with inclinations of 50° to 60° and even more. Such steeply dipping shales show magnificently in the east bank of East Canada creek, just below the Dolgeville power house [pl.8]. They are also well shown in some of the small creeks which cross the Little Falls fault line to the east and northeast of Little Falls.

### Folds

Since the rocks dip to the south and west, it follows that they rise in altitude going north. In mapping the formation boundaries it was soon discovered that the rise was not regular, but that a given rock horizon would remain at approximately the same altitude for a distance, then rise rather suddenly to a greater altitude, which was then held for a time, to be followed by another sudden rise. The sudden rises are indicative of rather steep (5°) southerly dips, followed by very flat dips which may be either southerly or northerly. These changes are plainly shown in the topography also, as will appear later. They are most marked in the near vicinity of the faults and are perhaps somewhat involved with them, but they are by no means confined to such situation.

About Middleville the dips bring out the fact that there has been a doming up of the rocks into a low arch there, in the center of which erosion has cut down to the pre-Cambrian. Southward from Middleville the Beekmantown-Lowville contact drops in altitude at the rate of about 100 feet to the mile. Northward from Middleville the northwest dips carry it down in that direction also, though much less rapidly, only about 20 feet to the mile. Three or four miles to the north, these are again replaced by the steeper southwest dips, and the contact rises in altitude. Here is therefore an instance of precisely the same sort of gentle folding that is in evidence along the fault lines.

In East Canada creek the same sort of thing is well brought out. At Ingham Mills the Beekmantown is exposed in the creek bed, with the Lowville, Black river and Trenton above. Just north of Ingham a rather steep northwest dip sends the four formations in rapid succession below the creek level. Sixty rods farther north, changed dip brings the Trenton again to the surface, and it so continues to the fault line, forming a low arch, since the dip changes again to the northwest before the fault is reached.

So far as observed, the axes of all these folds trend from east and west to northeast and southwest and pitch to the west and southwest. In nearly all cases the southern limb is steeper than the northern, the fold in East Canada creek just north of Ingham Mills being an exception.

In addition to these larger folds, small ones appear in many localities. These are best shown and most conspicuous in the Lowville limestone, though by no means confined to that formation. Such folds are beautifully exhibited in the creeks about Middleville, many of which flow down their westerly pitching sags. Plate 6 shows most excellently these slight folds as seen in the quarry in the Lowville limestone at Ingham Mills; but they show almost equally well in a great number of localities and seem as characteristic of the rocks hereabouts as are the larger folds.

## Faults

The Little Falls fault is the most westerly of a series of large, north-south breaks which cross the Mohawk valley, and is the only great fault within the map limits. The Dolgeville fault is of a lower order of magnitude, though still a considerable break. The Manheim fault (of the same order as the Dolgeville) lies just outside the map limits to the east. The second fault at Little Falls is a small affair and likely simply a branch of the main fault, which is very irregular and certainly branches somewhat, to the northward of Little Falls. Three other quite insignificant faults have been detected by the writer, and quite likely others exist. It seems very unlikely that the Little Falls fault marks the westerly limit of faulting. White has in fact noted two faults in the Trenton Falls district in addition to the one noted by Vanuxem, and quite likely others will be forthcoming when detailed mapping is carried northwestward.[1]

**Little Falls fault.** This fault was long ago described by Vanuxem, and recently in more detail by Darton. The latter was without an accurate base map on which to plot his results, and also lacked our present knowledge of the thickness of the various formations of the district, which is so largely due to Prosser's ex-

[1]Vanuxem, L. Geol. N. Y. 3d Dist. p.51-54.
White, T. G. N. Y. Acad. Sci. Trans. 15:80-81.

H. P. Cushing, photo.

Folds in the Lowville (Birdseye) limestone at Ingham's Mills. The basal layer is of Beekmantown age and the thin upper layer is Trenton, the Black River being absent. The folds have a low pitch to the s. w. A similar photograph might be taken at numerous other localities in the district, the low folds being characteristic of the region.

cellent work. There is therefore much in the way of details to be added to his description.

South of the Mohawk the topography gives no aid in the location of the fault line, as is the case at, and north of, the river. It has been traced for only some 3 miles in this direction, though it ought to be traceable beyond the map limits provided rock outcrops are forthcoming in that direction. Where last seen, its throw is sufficiently large to guarantee that it must extend some distance farther south.

North of the river the fault can be followed with great accuracy for 3 miles, both as a topographic feature and because of abundant rock outcrops. The actual fault plane is indeed exposed at several localities. Beyond, the topography locates it for 4 miles more, though there is a great scarcity of rock exposures on the downthrow side. Still beyond, up to the point where it passes beyond the limits of the map, its position can not be accurately located, since outcrops wholly fail on the downthrow side, the drift covering is very heavy on both sides, and the topography gives little assistance. Darton has mapped it for some distance farther, but the writer has not been over the ground.

The fault plane approaches verticality, and the downthrow is to the east [*see* accompanying maps and sections]. Darton estimated the throw of the fault at 310 feet, which is accurate for the spot where the measurement was made, but the place proves to have been unfortunately chosen, as will shortly appear. Prosser's accurately measured section at Little Falls furnishes the necessary data for estimating the throw there. The pre-Cambrian rocks are at the surface west of, and the Utica shales east of the fault line. The entire Beekmantown and Trenton, approximating 550 feet in thickness, are thrown out. In addition, the pre-Cambrian rocks rise to 200 feet above the river level at the fault line, while the Utica shale is at the river level on the east side, so that this 200 feet must be added to the other, giving 750 feet. In addition again an unknown thickness of Utica shale must be added. The Utica is heavily dragged upward near the fault, and, to obtain the actual throw, it should be flattened out. Two miles east of the fault plane, the upper portion of the Trenton-Utica passage beds is exposed near the mouth of Crum creek, at an elevation of 80 feet above the river, and on the south side, at Indian Castle, the same rocks show only 30 feet above the river level, with the Utica outcropping close at hand and only 20 feet higher up. The westerly dip would carry these rocks down to, and slightly below, the river level before reaching the fault line. Hence it is inferred that no great thickness of Utica shale, say 100 feet as a maximum, can be involved east of the fault line, and that therefore the throw of the fault at Little Falls is certainly as much as 750 feet, and lies somewhere between that figure and 850 feet.

South of the Mohawk, after climbing the hill, the Trenton and then the passage beds are at the surface on the west, and the Utica shales on the east of the fault. Since, however, the Utica is at the river level on the east side, since the altitude here is from 500 to 600 feet above the river, and since the dip is to the south about 100 feet to the mile, the horizon in the Utica must be in the neighborhood of from 650 to 700 feet above the base of the formation, so that the throw has not greatly diminished in this direction if it has at all.

The fault plane crosses the river with an approximately northeast and southwest trend. Within the first mile north of the river it swerves somewhat to the north, and then curves sharply westward through an angle of nearly 90°, continuing in this new direction for a mile, when it again swerves to the northward at a sharp angle. In this westwardly trending portion the fault is not a single sharp break as heretofore, but shows Utica shale on the downthrow, and Beekmantown rocks on the upthrow side, with a zone of much shattered Trenton between, having a varying breadth of from 100 to 300 yards; in other words, the fault is doubled through this part of its course with an intermediate shattered zone of no great breadth.

The accompanying section [fig. 5 *a*], made along the road which crosses the fault line midway in this part of its course, shows the usual conditions, though with less minor breakage than usual. Just to the west of the road in the fields, displaced blocks of the

Lowville and Trenton appear, close to the more southerly branch of the fault, with a nearly or quite vertical dip. Figure 5*b*, shows the conditions at this point. A few yards farther west there is exposed a rubble zone composed of broken up fragments of Beekmantown, Lowville and Trenton limestone, with an exposed width of 20 feet, which marks the fault plane of the south branch of the fault, the flat Beekmantown showing directly to the south, but no rock shows just to the north of the rubble zone.

The throw of the fault here can only be conjectured. The entire Trenton and passage beds are thrown out, together with

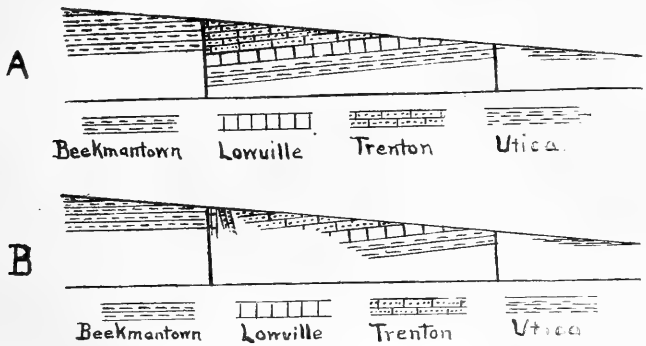



Fig. 5 Sections across the Little Falls fault. Scale, 75 yd=1 in.

unknown amounts of the Beekmantown and Utica. The exposed Beekmantown at the south is however very near the summit of the formation, so that no large amount of it is involved. On the dropped side the exposed Utica would also seem to be near the base of the formation, since the upper passage beds are exposed not far away. The throw would therefore seem not to exceed 300 feet here. This greatly diminished throw in a distance comparatively so short, coupled with the fact that still farther north the throw is approximately the same as at Little Falls, leads the writer to conjecture that quite likely the fault branches at the turn, and that this branch has remained undetected, owing to scarcity of outcrops. That the fault should suddenly diminish so greatly in magnitude, and then shortly reach again its former importance, might perhaps be brought about by its change in direction, but this would seem to be very unlikely.

At the second turn, where the fault swerves again to the north, a little brook crosses the fault line and exposes the very excellent section shown in figure 6, Utica shales, with gradually increasing dip due to drag, appear on the dropped side, the dip rising to 60° near the fault plane. Just at the fault a small block of black limestone like that of the passage beds appears with vertical dip, and then flat lying layers of the Trenton appear, beyond which nearly the full thickness of that formation and the overlying passage beds is shown. The throw here is even less than in the previous case, quite certainly under 300 feet, emphasizing the probable presence of an undetected branch fault. If such be not present, the throw of the fault has diminished two

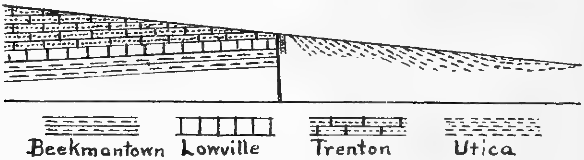



Fig. 6 Section across the Little Falls fault. Scale, 200 yd=1 in.

thirds in amount, and yet rapidly increases to the northward from this point up to its original size.

The trend of the small fault at Little Falls would carry it into the main fault at this corner, provided it extends so far. But the throw of this fault is very slight at best, so that it can not be traced beyond the river, and the junction is simply inferred.

Nearly 1 mile north of this locality a second fault appears, which seems clearly a branch of the main fault, though its actual point of union with that cannot be located. For a distance of a half mile (to the "Gulf" and a little beyond) the two faults can be traced, running nearly parallel for most of the distance, and giving rise to the apparent rock confusion at the "Gulf," which Darton seems to have interpreted as due to the depth of the stream cutting[1]. One of the sections of the structure section sheet map crosses the fault at this point and shows the writer's conception of the conditions. Darton's measurement of the throw

[1]N. Y. State Geol. 14th An. Rep't. 1894. p.37 and map opposite p.32.

of the fault (310 feet) was made here, and is accurate for the one fault, whose throw is just the thickness of the Beekmantown here, approximately 300 feet. But the real throw here is the combined throw of the two faults, and the second fault throws out the entire Trenton, the passage beds, and an unknown amount of the Utica, so that in the writer's judgment its throw is equal to, or exceeds that of the main fault, as from 100 to 200 feet of the Utica seem clearly to be involved. If that estimate be correct, the combined throw of the two faults here gives a total which does not fall far short of the throw of the single fault east of Little Falls.

One mile farther north the pre-Cambrian rocks appear at the surface from beneath the Beekmantown on the upthrow side of the fault, and thence northward are continuously at the surface on that side. The Utica is the surface rock on the other, but does not show in outcrop anywhere near the fault line. The more northerly of the sections of the structure section sheet crosses the fault line hereabout. The throw of the fault here is somewhat conjectural, since the amount of Utica involved is unknown. The Beekmantown has thinned to only about half the thickness present at Little Falls, but the Trenton and passage beds seem somewhat thicker here than there, though outcrops do not suffice for any precise measurement of their thickness. The horizon in the Utica would seem certainly higher than at Little Falls. It is thought that this, with the thicker Trenton, will largely make up for the diminished Beekmantown thickness, so that, while the throw here may be 100 feet less than at Little Falls, that is an outside limit.

All along this part of its course the absence of outcrops on the east side of the fault makes it impossible to determine whether the fault branches or consists of a single break, though in the absence of any evidence to the contrary the latter is regarded as most probable.

**Dolgeville fault.** This fault can be traced for only 1½ miles, beyond which its farther extent in both directions is concealed by heavy drift deposits. To the south it must soon disappear because its throw is reduced to zero. Followed northward from its first point of appearance, its throw increases with unusual rapidity, as noted by Darton.[1] The last point of identification is at the High falls, below Dolgeville, beyond which it can not be traced because of utter lack of outcrops for several miles.

Where the fault crosses the creek, its most southerly point of exposure, the creek has a rock bottom, and the section furnishes interesting evidence of the manner in which the fault is dying out. The dips are rather high, from 30° to 60° on the downthrow side, and the layers have been beveled to an even surface by the cutting action of the stream, so that at low water the section shows mag-

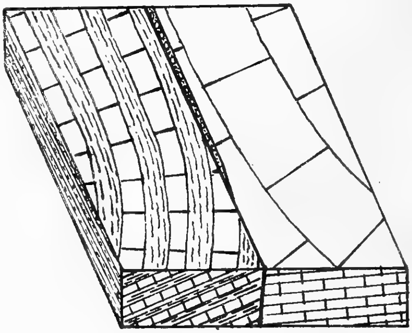
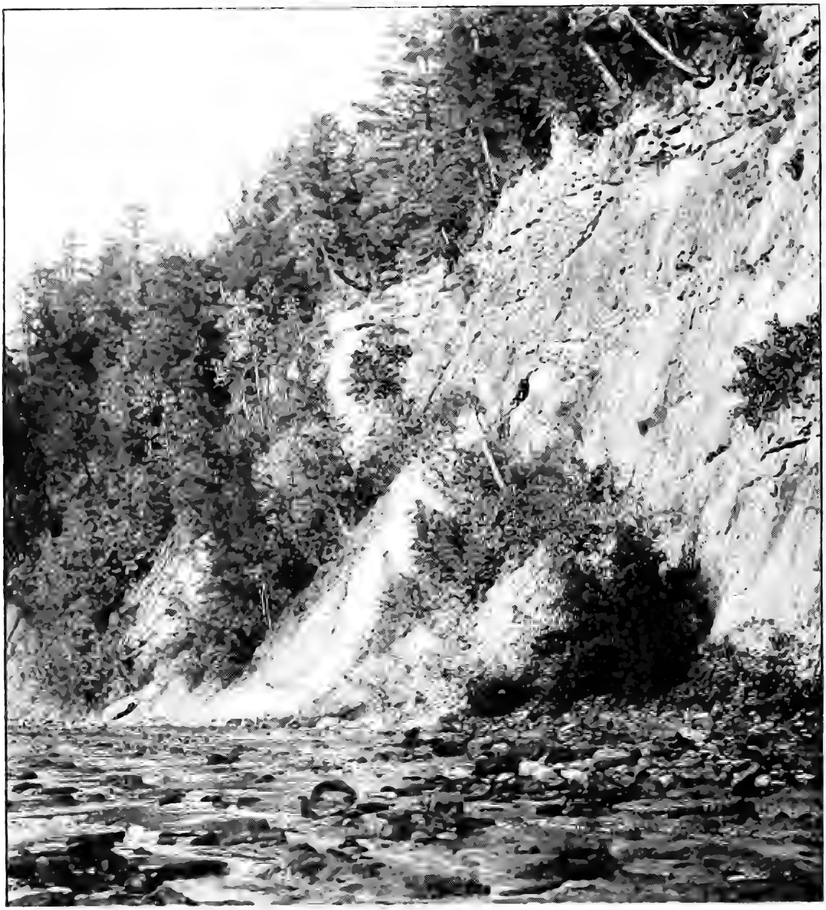


Fig. 7 Plan and section to illustrate the conditions where the Dolgeville fault crosses East Canada creek. Trenton limestone is at the surface on the east side, and the alternate shales and limestones of the passage beds on the west. The divergent strike brings lower beds in succession to the surface on the west, or downthrow side, and higher beds on the east side, with consequent diminution of throw.

nificently. Figure 7, though not an accurate scale drawing, reproduces the observed conditions quite faithfully. There is a breccia zone a few inches wide along the fault line. The spreading produced by swerving of the strike is most marked on the west side, which coupled with the high dip there, brings successively lower layers to the surface with some rapidity. The fault seems to pass into a monoclinal fold southward, which fades out in its turn, and this seems a step in the transition.

Some 50 rods north of this point another smaller fault appears in the east bank of the creek. It shows Utica shale on both sides and has but an insignificant throw. Judging by the

[1] Darton gives four sections across this fault, *op. cit.* p.41.



H. P. Cushing, photo.

The Dolgeville fault exposed in the bank of East Canada creek. At the right the fault is at the base of the vertical cliff, which consists entirely of Beekmantown layers, the Lowville capping not showing in the view. Over most of the cliff the fault breccia is still in place, so that the stratification shows only here and there. The fault plane is seen to diagonally ascend the cliff face from right to left, commencing at the dark bush and following the line of bushes. The sloping surfaces below are those of the updragged layers of Utica shale, whose stratification may be made out at the extreme left.

drag, it also throws to the west, as does the main fault, and it is likely a small branch of the latter. It would indicate that the dying out of the fault is probably produced in part by branching.

Between these two points a bend in the creek carries its east bank back against the fault plane, which here forms a nearly perpendicular cliff some 80 feet in hight, rising directly from the creek margin. The topographic map is not quite accurate here, so that it is impossible to properly show this feature upon it, an excessive bend and an incorrect course being required to bring the fault to the creek on the map as it stands. The fault plane continues at the margin for only a few yards, then runs diagonally up the cliff face, updragged Utica shale appearing at the base,

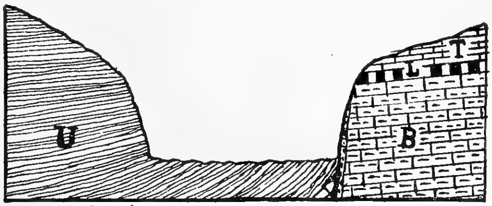



Fig. 8 Section across East Canada creek at the point where the Dolgeville fault forms the east bank. U=Utica shale, T=Trenton limestone, L=Lowville limestone and B=the Beekmantown beds. The fault breccia is also shown. The section crosses the east wall at the right in plate 6.

and running constantly higher, till it forms the entire hight of the cliff. The features are magnificently shown, but are unfortunately difficult to photograph satisfactorily, plate 7 showing them as well as it is possible to bring them out. Figure 8 gives a scale drawing of the section here. A fault breccia from 2 to 5 feet wide, consisting of a multitude of angular fragments of all sizes, in which Beekmantown material largely predominates, but with a considerable contribution from the Lowville and Trenton also, embedded in a black, fine grained matrix, which seems largely of Utica origin, occurs here. There is a layer of chert near the summit of the Beekmantown here, as elsewhere, and this has naturally been a large contributor to the breccia. It has been also largely impregnated with pyrite or marcasite, which forms at times nearly the entire matrix, and whose decomposition and oxidation has blotched the cliff with iron stain. The summit layers of the Beekmantown are also much more pyritiferous than usual. The fault breccia still clings to much of the cliff face, and since the fault plane is nearly vertical, having only the slightest possible inclination westward, it appears much like a vertical dike along the cliff wall.

About 75 feet thickness of Beekmantown rocks is exposed in the cliff above the creek level, while lower Utica appears at that level on the opposite side of the fault; hence the throw comprises that thickness of the Beekmantown, the entire Trenton (inclusive of Lowville and Black river), from 40 to 50 feet thick hereabouts, and an unknown amount of the passage beds and lower Utica, of no great thickness however. The throw is therefore in the neighborhood of 150 feet, while $\frac{1}{4}$ mile to the south, where the fault crosses the creek it will not much exceed 25 feet.

From this point northward to the Dolgeville power plant, at the High falls, a distance of about a mile, the fault runs parallel with the creek and not far distant from it, with steeply updragged Utica shales forming the easterly wall of the gorge. These show beautifully at the power plant [pl. 8 and 9]. A short distance to the east is an old quarry in the Beekmantown at a level 140 feet above the creek bed below the fall. Moreover this is not the summit of the Beekmantown though the actual horizon is unknown. More than this thickness of this formation is therefore involved in the fault here, along with the entire Trenton and passage beds, and an unknown, but here considerable amount of the Utica, the throw here being certainly as much as 300 feet and likely more. The increase in throw has therefore been maintained northward, though apparently at a somewhat less rapid rate than at first.

Beyond this point the creek swerves away from the fault, which becomes wholly lost in heavily drift-filled country.

One mile above Dolgeville a small fault shows in East Canada creek just at the second big bend beyond the village. The fault is in the Utica shales though the associated thin limestone bands indicate that the horizon is not far above the passage beds. The

H. P. Cushing, photo.

Utica shale, east bank of East Canada creek, at the power house near Dolgeville. The steep dip is due to updrag of the Dolgeville fault. It shows best in the left center. The tipping has made one of the joint sets horizontal, and these horizontal joints simulate bedding on the right. The joints are therefore older than the faults.

H. P. Cushing, photo.

Fall in East Canada creek at the power house near Dolgeville. The cliff shown in plate 8 forms the right wall of the gorge just below the fall. The shale here is therefore a little farther away from the fault. The dip still shows the effect of drag, and in increasing amount from left to right, becoming suddenly much steeper at the extreme right.

fault is a small one of unknown throw, at the crest of a low anticlinal fold, with sharp drag on the east side. It is a fair sample of the insignificant faults of the vicinity.

All the Mohawk valley faults, so far as known are normal faults with nearly vertical hade. Nearly all of them downthrow to the east, the only exceptions to this rule known in the region being two of the faults which occur here, the Dolgeville, and the small fault at Little Falls. These both downthrow to the west.

### Foliation

The excessive metamorphism to which the pre-Cambrian rocks were early subjected has produced in them a foliated structure, in a varying degree of perfection; varying not only with change in the character of the rock, but from place to place in the same rock. Igneous and aqueous rocks are alike foliated, though commonly the latter are much more distinctly so than the former. The old bedding planes of the aqueous rocks are so obliterated that they have not been made out and it can not be stated what relationship, if any, they bear to the foliation planes. Of the old igneous rocks the syenite at Middleville shows the least foliation of any. The corresponding rock at Little Falls is however excessively foliated, though varying much in amount from place to place. The syenites and granites to the northward are thoroughly gneissoid.

The foliation planes of the district have a nearly east and west strike. Of the very large number of readings taken on them about 65% lie between n. 70° e. and n. 90° e., and the larger part of the remainder do not exceed these limits by more than 10°. Locally however there is considerable variation, largely due to folding.

The dips of the foliation planes are now to the north, now to the south, showing that they have been folded. Sometimes changes in dip direction are frequent showing small folds, but in the main the folding is on a large scale. In the majority of cases the dips are gentle, not exceeding 20°, but there are many instances of steeper dips, even reaching 90°, and in many places the rocks are excessively and minutely folded and crumpled.

Where the strike swerves to the northwest from its usual direction, the dip is usually found to be to the north, and a corresponding change to the northeast is accompanied by a south dip. Usually a change in dip from north to south is accompanied by a swerving of the strike as above noted, though, where the dips are gentle, the change is apt to be very slight. But, so far as it goes, the evidence indicates a general pitch of the folds to the east.

## Joints

**Pre-Cambrian rocks.** The pre-Cambrian rocks are invariably much jointed. The larger number of the joints are vertical, or nearly so, though they may depart from the perpendicular by varying amounts up to as much as 30°. It is an exceedingly difficult matter to reduce these joints to any system, since they show a surprising lack of uniformity in direction. Most individual exposures show vertical joints in only two directions, though sometimes a third, and rarely a fourth is added. While these two directions are tolerably constant locally, they vary widely from place to place. A large number of readings have been taken on these joints, and, when it is considered that the area on the map occupied by these rocks is only some 50 square miles, the great variation that they show in direction is surprising, and it seems almost futile to attempt to reduce them to any system. To illustrate, 129 readings on these joints were so selected as to represent rather uniformly the pre-Cambrian area, the readings rejected being some of those from places where, because of frequent outcrops, many more than the average number were available. These were plotted as shown in figure 9. In general, readings can not be taken closer than within 5°; and all others have been plotted at the nearest 5° point (33° being made 35° and so on). On this basis there are 36 possible directions of joint planes, and out of these 31 actually occur. Were the joint planes regular in direction, this would imply a great number of joint systems, but the diagram is itself prima facie evidence that they are not regular. Moreover at most outcrops but two systems are to be seen, and also at most outcrops one or both sets are actually seen to be very irregular, and that in two ways; first, the joints are often observed to curve, and second, the various planes of the same system are often far from parallel. Hence the usual imperfect exposures in the woods, which form the larger number of the pre-Cambrian exposures, and which are apt to show only one or two planes of a set, are likely to give widely varying results.

In many of the pre-Cambrian exposures the two sets of joints shown are, the one parallel to, and the other at right angles to the strike of the rocks. The other exposures show joints which do not conform to the strike, one set making an angle of from 15°

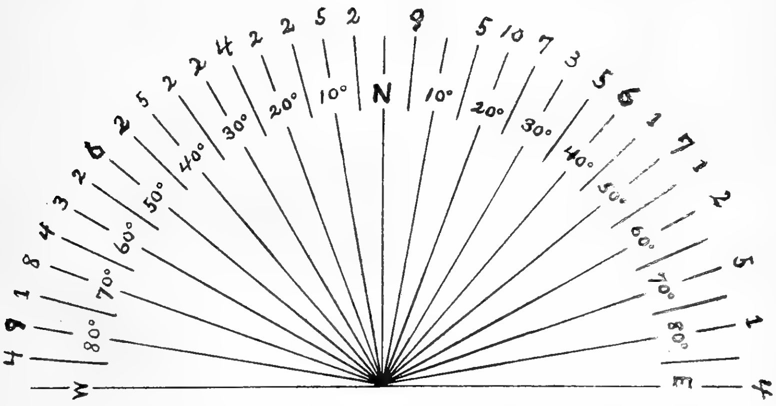



Fig. 9 Diagram of 129 readings on joints in the pre-Cambrian rocks. The inner row of figures represents the points of the compass, in degrees from the true north. The outer row gives the number of readings on joints for each compass direction.

to 45° with it. Sometimes this is brought about by a swerving of the strike while the joints hold their direction, as is the case at Little Falls; at other times it occurs when the strike has remained constant in direction. This latter fact seems to the writer to imply perhaps two groups of rather irregular joints; and the diagram, figure 9, would seem to bear out such an interpretation. Bearing in mind that the curving of the joints causes considerable latitude in the direction of a given set, the diagram shows that the larger number of readings lies between n. 5° e. and n. 25° e. and the next larger number between n. 65° w. and n. 85° w., the two being approximately at right angles. A less well defined group is possibly indicated in the northeast and northwest directions.

The joints in the pre-Cambrian rocks are vastly better shown at Little Falls than at any other locality on the sheet, the steep joint cliffs in the long railway cuts there being familiar to everyone. There are two conspicuous sets of vertical joints here which are at, or nearly at, right angles to each other (the readings show an angle varying between 70° and 90°). Both sets vary somewhat in direction; one gives readings of from n. 70° w. to n. 90° w., the other from n. 20° e. to n. 35° e. There is however a third set to n. 10° w. or thereabouts, which is locally the most conspicuous of all. The strike of the foliation planes at Little Falls varies between n. 60° w. and n. 90° w., being sometimes parallel with, and sometimes making an angle as high as 40° with the n. 50°-70° w. joint set. This plainly indicates that the variations in direction of joints and foliation are independent of one another.

In addition to the vertical joints, there are at least two sets of much less steeply inclined joints. These are in the majority of cases dip joints, following closely the direction and inclination of the foliation planes. They are most numerous and pronounced in the Grenville gneisses, but occur frequently in the igneous rocks as well, being specially noteworthy in the granitic gneisses associated with the Grenville rocks. The other set is at right angles to the first in regard to both strike and dip, and is not so well marked. Both seem to be compression joints, and the fact that the strike of the second set is at right angles to the foliation strike suggests that the two sets are probably due to compressive forces acting at different times and in opposite directions.

**Paleozoic rocks.** In these the compression joints are lacking, but the vertical (tension) joints are abundantly developed, and when plotted show the same wide variation in direction found in the pre-Cambrian rocks, so that it is not certain that any set is present in the latter which is not also found in the former. There are however more readings in the direction n. 70° e. than in any other, giving this direction much greater importance than in the pre-Cambrian rocks.

Since the Paleozoic rocks are folded only in the most gentle fashion, the joints have likely no connection with the folding.

Their great irregularity may perhaps indicate that desiccation was a prominent factor in their production. Of these rocks the Utica shales show the most numerous and sharpest joints, and they are least in evidence and most irregular in the Beekmantown rocks. Three sets are often present in the Utica, because of which the harder layers break out into triangular blocks.

Though the fact can not be deduced from a comparison of the readings, it is quite certain that the pre-Cambrian rocks were jointed before the deposition of the paleozoics. The prevailing east-west trend of the diabase dikes, in the regions where these occur, would seem demonstrative of a set of joints having that direction, and suggestive of the probability that that was the only good set.

## SOME OSCILLATIONS OF LEVEL DURING THE EARLY PALEOZOIC

Certain matters which are in no sense novel call for consideration here. The main propositions have been already advanced by others. But the detailed study of the Little Falls district has brought out evidence of the verity of certain notions long held which is new, and also the facts can perhaps be marshaled more convincingly than has been the case hitherto.

### Paleozoic overlap on the pre-Cambrian floor

It has already been stated that in pre-Paleozoic times the Adirondack region was a dry land area for a vast length of time, and that a subsidence commenced during the Cambrian, in virtue of which the sea slowly encroached on the region from all sides, that it became an island in the midst of the sea, and that by the close of the Lower Silurian the entire region was either entirely submerged or else so nearly so that but little of it still protruded above the waves; that, as it sank, each succeeding rock formation deposited on the floor of the encroaching sea, would extend farther in on the old land surface than the previous one, so that each would be in turn found resting on that surface in going toward its center, constituting what is called overlap. This is in the main the ordinary conception of this portion of the history of the region, and has been specially elaborated by Mr C. D. Walcott, on various occasions. Since Paleozoic deposition ceased in the region, and it became anew a land area, it has been decapitated by the prolonged erosion which has followed. The Paleozic cover has been entirely worn away from the heart of the Adirondacks, these rocks now appearing as a fringe about the district. In the past they extended farther in than they do now; the erosion of the future will remove them from districts which they now cover, increasing the extent of the area in which the older rocks form the surface exposures. The conditions along the edge of the fringe, so far as they differ, depend not only on

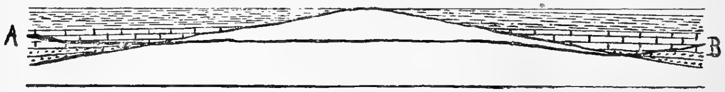



Fig. 10 A reproduction of fig. 3, to illustrate the supposed condition in the Adirondack region at the close of the Utica period. Subsequent erosion has worn off the region down to the line AB, reexposing the pre-Cambrian rocks over a wide area, and leaving the Paleozoic rocks confined to the flanks of the region.

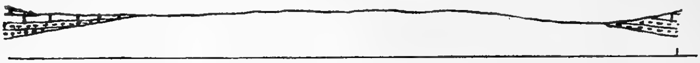


Fig. 11 The region after the wearing away of the upper portion, the line AB of the previous figure forming the surface. Erosion has cut more deeply on the right hand side than on the left. On the right the basal sandstone is exposed, lying uncomformably on the old surface, with the overlying limestone appearing farther to the right. On the left the limestone appears lying on the old surface, erosion having nowhere cut deeply enough to expose the underlying sandstone.

possible differences in the conditions of original deposition on different sides of the region, but also on the depth to which erosion has since cut. If we should assume that the Potsdam, Beekmantown, Trenton and Utica formations were successively deposited all about the Adirondacks, progressively overlapping toward the center of the district, then it is theoretically quite possible that we might today find the Potsdam resting on the pre-Cambrian here, the Beekmantown there, and the Trenton or Utica elsewhere, for the reason that more rock had been removed by erosion in the former case than in those following, that in them erosion had not yet cut deeply enough to bring the edge of the Potsdam to daylight from underneath the overlying and overlapping Beekmantown [fig. 10, 11].

Within the map limits the Potsdam sandstone is wholly absent, the Beekmantown resting on the old, pre-Cambrian surface. The

Potsdam may be absent because of overlap, in which case it should be present to the south and west, under cover of the Beekmantown and still later rocks which are at the surface in those directions; or it may be absent because of nondeposition, the subsidence of the region hereabout not having commenced till the close of the Cambrian; or, lastly, it may be absent as a recognizable lithologic formation comparable with the Potsdam sandstone, for the reason that no sand was brought into the upper Cambrian sea here by currents or by streams, a limestone or a shale or both having been deposited instead. The latter alternative can only be determined by the fossils, and in their absence it is impossible to affirm that the basal portion of the Beekmantown may not be of Cambrian age, though it is not probable.

Such evidence as has been brought to light up to the present, is not sufficient to enable us to pronounce affirmatively in favor of any of the above suppositions. One or the other of them must represent the actual facts of the case. Such evidence as is available comes from the deep wells which have been drilled to the west and northwest of the district. Of these there may be specially mentioned the Remington well at Ilion, less than 3 miles west of Herkimer; the Globe mills well at Utica and the Campbell well 3 miles west of Utica; the Rome Brass & Copper Co. well at Rome; and finally the wells in Pulaski and Orwell, Oswego co.[1] These wells were all drilled with churn drills, and the mashed rock fragments produced by this method of drilling are often difficult of proper determination. Had we diamond drill cores from them, the evidence would be all that could be asked. These wells have all begun in, or above, the Utica shale horizon, and have penetrated the entire rock thickness down to, and a varying amount into, the pre-Cambrian. They have gone through the entire rock series here in question, but the fragmental

[1] Prosser, C. S. Am. Geol. 25:131–44.

——— Geol. Soc. Am. Bul. 4:100–1.

Walcott, C. D. Am. Ass'n Adv. Sci. Proc. 36:211–12.

Orton, Edward. N. Y. State Mus. Bul. 30, p.426–50.

samples saved do not suffice properly to identify the rocks. The confusion which exists is in the proper discrimination of the Potsdam from the Beekmantown on the one hand, and from the pre-Cambrian on the other. The basal Beekmantown is often very sandy; and the light colored pre-Cambrian gneisses will furnish a rock powder exceedingly difficult to distinguish from the Potsdam except by the most searching microscopic examination, possibly not even by that. Thus the earlier interpretations of the Globe and Campbell wells assigned from 300 to 400 feet of the rock passed through to the Potsdam. Prosser's later study of the Rome well led him to the belief that the Potsdam was not present there, the Beekmantown resting on the pre-Cambrian, with a total thickness of 475 feet. But the basal 275 feet of the rock referred to the Beekmantown seems not at all calcareous, so that its reference to the Beekmantown is somewhat problematic. Lithologically it certainly does not belong there. On the other hand, as Prosser points out, it is very probable that much, if not all of the rock referred to the Potsdam in the two Utica wells may in reality be pre-Cambrian.[1]

As might reasonably be expected, the Ilion well exhibits a section very like the surface section at Little Falls. The Beekmantown is a little thicker, but it shows calcareous matter down to its very base, just as it does at Little Falls. Since Ilion and Little Falls show such similar sections, though 9 miles apart, it is exceed-

[1]Through the kindness of Professor Cushing, I have had the opportunity of reading the above remarks concerning the Beekmantown limestone in the Rome well. Data obtained after the preparation of my paper on "Gas-well Sections in the Upper Mohawk Valley and Central New York" leads me to accept fully Professor Cushing's conclusions. Of the 475 feet referred to the Calciferous [Beekmantown] formation in the Rome well (*loc. cit.* p.139, 140, 143), I would now refer the upper 190 feet, from 1085 to 1275 feet in depth, to the Beekmantown limestone. The lower 285 feet, from 1275 to 1560 feet, are apparently not calcareous and are composed mainly of quartz sand. It is not improbable that part of this thickness, and perhaps all, belongs in the Potsdam sandstone; but I am inclined to think that it is a difficult matter to say where the line between the Beekmantown and Potsdam formations shall be drawn.

C. S. Prosser

*Mar. 10, 1902*

ingly improbable that, in going the 12 miles farther west to Utica, any such thickness of Potsdam as 300 feet could have crept in in the interval. On the other hand, the great thickness of noncalcareous layers which Prosser has included in the Beekmantown in the Rome well, would seem to the writer to indicate that some Potsdam might be present, both at Rome and at Utica. The reference of 285 feet thickness of noncalcareous sandstones to the Beekmantown seems to the writer hardly justifiable. Orton has classed the 475 feet of rock between the Trenton and the pre-Cambrian in the Rome well as Potsdam and Beekmantown (Calciferous), without attempting to draw any line between the two, and this would seem all that we may do safely at present, though there is unquestionably some justification for Prosser's argument, based on the rock thickness, 475 feet being closely the thickness of the Beekmantown at Ilion and Little Falls. If it be all Beekmantown at Rome, the formation has undergone a pronounced lithologic change in the interval.

The Oswego county wells, though many miles distant to the northwest (Pulaski is nearly 40 miles from Utica in that direction), seem to give significant evidence in this connection. Prof. Orton reports 156 feet of sandstone which he calls Potsdam, in the Central Square well between the limestones and the pre-Cambrian; also a 50 foot thickness of similar sandstone in the Parish well. In the Pulaski wells he reports from 40 to 90 feet of rock thickness between the Beekmantown and the pre-Cambrian, the general section being

| | |
|---|---|
| Beekmantown | |
| Greenish sand | 10–40 feet |
| Black limestone | 20–40 feet |
| Greenish sand | 5–10 feet |
| Pre-Cambrian | |

In the Stillwater well there are similar sands with limestone lying on the pre-Cambrian, the limestone being 6 feet thick, with 18 feet of calcareous sandstone below and 25 feet of green and white sandstone above. Fossil fragments occur in the limestone chips brought up from this stratum, from which its Upper Cambrian age was determined.

These records seem to demonstrate the presence of deposits of Upper Cambrian age in Oswego county, under cover of the newer rocks and at a distance of some 20 miles from the nearest surface pre-Cambrian outcrops to the eastward. They have not been reported in surface outcrops along the pre-Cambrian boundary, the overlying Silurian limestones seeming to lie directly on the pre-Cambrian there. Apparently we have here direct evidence of overlap, and also evidence of a considerable change in the lithologic character of the Upper Cambrian, it being no longer typical Potsdam sandstone. Nor is the formation here of any great thickness, as compared with the Potsdam sandstone of the St Lawrence and Champlain valleys. But in answer to this last, it might be argued that the diminished thickness here was due to overlap, and that sufficiently deep wells located some few miles to the westward of the Oswego county wells might show a greatly increased thickness of Upper Cambrian rocks, and with our present knowledge this argument could not be gainsaid.

In summing up, it may be said that we have in Oswego county good evidence of the presence of the Upper Cambrian horizon, and that it is absent along the pre-Cambrian boundary because of overlap. Along the line from Rome to Little Falls the evidence is not decisive as to the presence of the Upper Cambrian, nor is there any special indication of thickening in the whole series of deposits between the Trenton and the pre-Cambrian, as should be the case were the conditions those of overlap. But there is the possibility that the Potsdam is represented in the Rome and Utica wells, though it is only a possibility and does not enable us to decide definitely whether the Upper Cambrian was ever deposited anywhere within the limits of the upper Mohawk valley or not.

**Beekmantown overlap.** The uncertainty which exists in regard to conditions hereabout in Potsdam times, ceases with the beginning of Beekmantown deposition. The evidence of Beekmantown overlap is clear and decisive.

The Beekmantown at Little Falls is 450 feet thick. Northward from there, following first the fault line and then the Beekmantown–pre-Cambrian boundary, the thickness gradually diminishes. At Diamond hill it has shrunk to about 100 feet. Beyond that point exposures are not sufficient to determine the amount absolutely, since the base nowhere outcrops. The last Beekmantown exposures seen are located nearly 2 miles south of the north boundary of the map sheet. While the thickness here can only be inferred, it can be safely said that it can not exceed 40 feet, and is likely not over half that amount.

One mile farther to the northwest Trenton limestone and pre-Cambrian gneisses are exposed sufficiently close to one another to almost preclude the possibility of the presence of the Beekmantown. Darton has however mapped it as extending some three or four miles farther to the northward. The writer has not been over the ground in that direction and does not know whether Darton's mapping there is based on actual outcrops or on inference. In either case we are here near the point of disappearance of the Beekmantown, beyond which the Trenton overlaps it on the pre-Cambrian.

There is an exceedingly interesting section at Diamond hill, demonstrating a local overlap of the Beekmantown there, which may be taken as illustrative of the whole process. As has already been stated, there is an exposure of the contact of the Beekmantown on the pre-Cambrian in the bank of Spruce creek at Diamond hill. Here the top of the pre-Cambrian is at an elevation of 1280 feet above sea level. But only a few rods to the northwest is a low knoll, all over which pre-Cambrian rocks are exposed, which reach an elevation of 1360 feet. Plainly we are here dealing with a low pre-Cambrian knob or hillock at least 80 feet in original hight, around which the Beekmantown was deposited before overtopping it. Sixty rods west of Spruce creek a little brook comes down which exposes a most interesting section of Beekmantown rocks some 25 feet in thickness. Then follows a gap of 25 yards in which are no exposures, after which are abundant outcrops of pre-Cambrian gneisses, the nearest to the Beekmantown rocks being at least 15 feet above them in elevation. That there is no fault between the two is attested by the contact in Spruce creek, and by the study of the abundant outcrops on all sides. The Beekmantown rocks are quite sandy, and yet strongly calcareous (or rather dolomitic, effervescing only slightly with cold, but abundantly with hot acid). They contain numerous pebbles, not only of quartz but also of gneiss, identical with the white, quartzose Grenville gneiss of the hill. Moreover, these pebbles are considerably more numerous in the uppermost Beekmantown layers than in those below, for the evident reason that the exposed portions of the lower layers are at a greater distance from the pre-Cambrian rocks than is the case with the upper ones, that is, the pebbles increase in number with approach to the old shore line, as they would be expected to do. The accompanying section, drawn to scale, shows the actual conditions as observed, and also by dotted line the approximate position of the pre-Cambrian slope, the base on which the Beekmantown was deposited. The section seems to the writer to be decisive as to overlap.

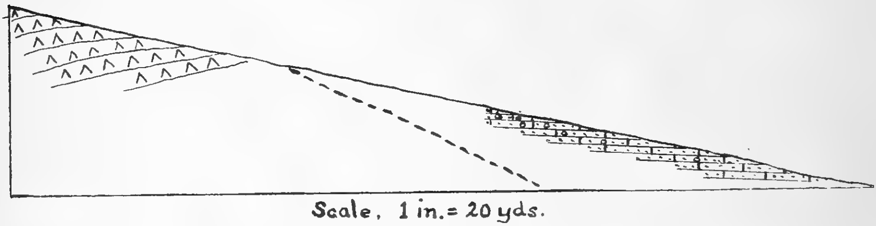



Fig. 12 Section near Diamond hill showing overlap of Beekmantown on pre-Cambrian. The Beekmantown strikes n. 45° w., dip 5 ° s. The pre-Cambrian rocks strike n. 80° w., with low northerly dip.

This overlap of the Beekmantown denotes a progressive sinking of the immediate district during Beekmantown time. Its successive layers from base to summit must rest in turn on the old rocks, after which the Trenton rests thereon. There is no known locality in northern New York where the Utica may be found resting undisturbed on the old surface, the reason being that erosion has everywhere cut below this horizon and removed every scrap of the Utica from such situation. But there seems no reason to doubt that the progressive subsidence continued intermittently during Lower Silurian time and for an unknown length of time thereafter.

### Character and slope of the pre-Cambrian floor

The pre-Cambrian rock exposures of the Little Falls outlier extend for 2 miles in an east and west direction, with a general breadth of a half mile. While the contact with the overlying Beekmantown formation is actually shown in but two places, it is but scantily covered elsewhere, being within a few feet of showing continuously on both sides of the river. The surface on which the Beekmantown rests is surprisingly smooth and even. There are not even minor irregularities in it. For the first mile (between the two faults) it is nearly horizontal, though with slight westward inclination. Beyond the westerly fault it drops to the westward at the rate of 200 feet to the mile up to the point of disappearance beneath the river level. In this western portion the Beekmantown rocks slightly overlap on it, their fall to the west being slightly less rapid. The same may be true of the remainder though it is not certain.

The outlier at Middleville is not sufficiently extensive to afford much evidence in this connection. The creek has here cut down on the summit of a low fold. There is no evidence here of irregularity of original surface, but there is slight opportunity for such evidence.

The small outlier at the "Gulf", 2½ miles northeast of Little Falls, seems to represent the summit of a small knob of the old surface projecting up into the overlying Beekmantown. But it can not be much of a hill at best. The pre-Cambrian surface, at the fault line east of Little Falls, has an altitude of 700 feet; 4 miles to the northward, where it reappears from underneath the Beekmantown rocks to the west of the fault line, its altitude is 1000 feet; the little outlier is midway between the two and is at 860 feet elevation.

Along the main line of contact between the Beekmantown and pre-Cambrian the same evidence of comparative evenness of the rock surface on which Beekmantown deposition took place, is presented. Exposures are not all that could be asked, and at Diamond hill there is evidence of a low hill rising some 100 feet above the general level, that being the greatest irregularity of surface indicated anywhere within the map limits. The surface seems to have been worn down to that of a gently sloping plain, above whose level, occasional low, rounded hills arose.

Though this evidence is meager in amount, and needs corroboration from adjoining districts, it seems specially important in view of the fact that Professors Kemp and Smyth, and the writer also, have found evidence to show that, in the St Lawrence and Champlain valleys and vicinity, the surface on which the Potsdam was deposited was considerably more uneven than this. In other words, the surface on the south was worn down to a nearer approach to base level than was the case farther north.[1] This may be accounted for in part by the fact that, since the Potsdam lies on the old surface there and the Beekmantown here, the surface here was a land area and undergoing wear during Potsdam time, or was a land area longer. The probable length of time involved would however seem insufficient to account for all of the observed difference.

A more probable explanation would seem to be that we are dealing here with a plain of marine erosion, and that its subsidence was slow, giving opportunity for the cutting of a considerable submarine terrace; whereas on the north the rather rapid subsidence during the Potsdam did not permit of the production of such a smooth and well defined bench, the district passing beneath the sea practically as subaerial erosion had left it, except for the removal of the weathered material.

**Slope of the surface on which the Beekmantown was deposited.** The Beekmantown rocks at Middleville are 200 feet in thickness. Seven miles to the northeast they have nearly or quite disappeared, and the Trenton rocks are overlapping on the pre-Cambrian. The pre-Cambrian surface has risen 800 feet in the interval, while the base of the Trenton has only risen 600 feet, the difference of 200 feet representing roughly the inclination of the surface on which

[1] Professor Kemp states in a letter that he has come to the same conclusions about the greater evenness in the south, away from the higher hills of the interior, from observations at the "Noses" and in the southern Hudson-Champlain valley.

deposition was taking place, indicating a slope of nearly 30 feet to the mile.

From Middleville to Ilion, in the opposite direction, the distance is 9 miles. The Beekmantown thickens 275 feet in the distance, from 200 to 475 feet, or again 30 feet to the mile.

From Little Falls northward to the spot of Beekmantown disappearance the distance is 15 miles. The Beekmantown rocks at Little Falls are 450 feet in thickness. This wholly disappears in the 15 miles, indicating again a slope of 30 feet to the mile.

The two latter measurements are both made in a nearly southerly direction and agree very closely. The first measurement is made in a southwesterly direction and falls somewhat short of the other two, which would indicate that the general slope of the surface was to the south. It is not meant to imply that this slope was maintained over any great distance, nor that it was uniform throughout, nor does it follow that the whole thickening to the south is due to overlap. But the figures do seem to demonstrate a southerly sloping sea floor, whose rate of slope was not over 30 feet to the mile, though it may have been somewhat less than that, and which is at least maintained throughout the area covered by the map.

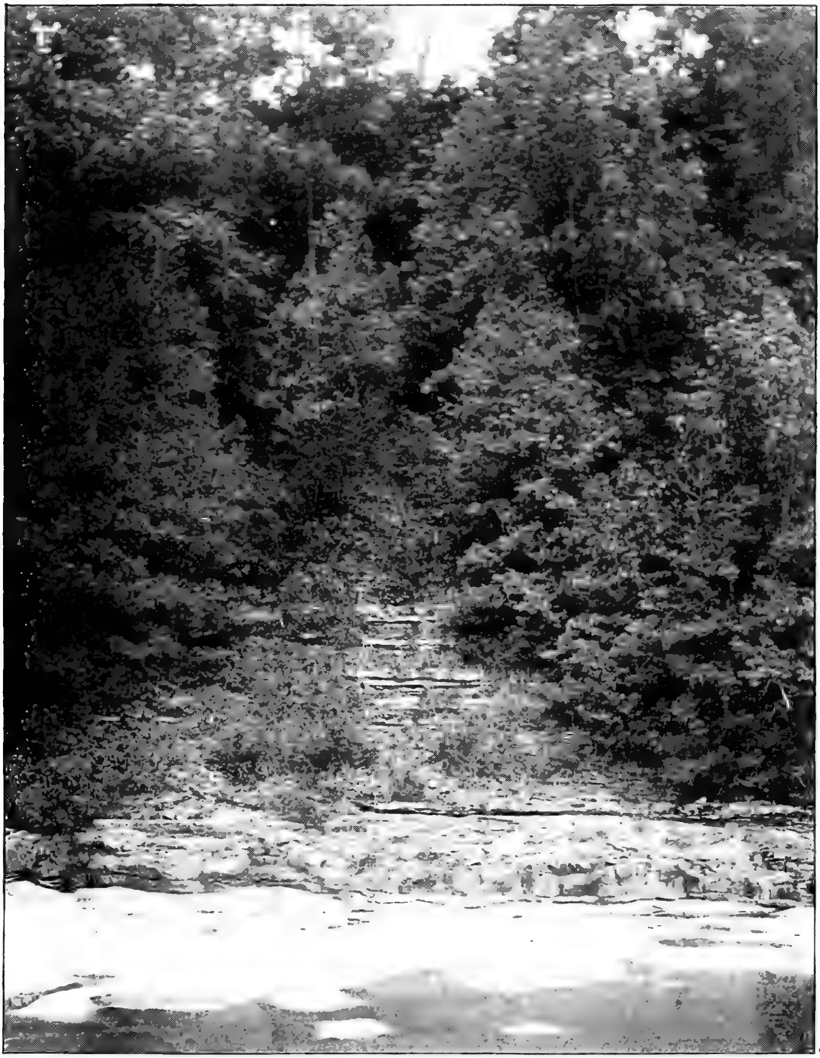
As will be immediately shown there was some disturbance of the district during the early Trenton which must have affected this slope both in direction and in amount. Unfortunately also no quantitative data for determining the amount of this effect are at hand. But the effect could not have been great. If we assume that the effect was nil, and allow the Trenton rocks a thickness of 300 feet, which is close to their maximum hereabouts, then they would have only reached in 10 miles farther on the old surface than the Beekmantown rocks do, if the same rate of slope was maintained, beyond which the Utica would have overlapped on the surface. Nor would the Utica and Lorraine shales of the Hudson formation have extended in more than 30 miles farther over the region, even on the assumption that they were deposited to their full thickness, which is not likely. This line of evidence would therefore, so far as it may be worth anything, seem to indicate that the southern Adirondack region could not have been completely submerged at the close of the Lower Silurian, much less so at the close of the Trenton. Here again the evidence is rather opposed to that on the north side of the region, as will be shortly shown.

### Unconformity at the base of the Trenton

The great thickness of the Trenton formation at Trenton Falls, and its rapid diminution in thickness eastward across the area of the map have already been noted, together with the variation in thickness of the Lowville down to complete absence, the presence of the Black river limestone only here and there, and the fact that the passage beds between the Beekmantown and Lowville are not always present. Vanuxem, Darton and Prosser have all published valuable data along this same line, derived from the Mohawk valley to the eastward. The most significant section is that at Canajoharie, described by all three observers as showing a distinct, though slight, erosion unconformity between the Beekmantown and Trenton [*see* pl. 10, and compare with pl. 5]. Prosser measured but 17 feet of Trenton here, and this seems to represent only the upper beds of the formation, while both the Lowville and Black river are wholly wanting. At Sprakers, 3 miles farther east, Prosser's section shows again but 17 feet of Trenton, with no sign of the Lowville and Black river. Nothing is said about an unconformity at this point and apparently the actual contact is not exposed.

Eastward from Sprakers the Trenton slowly thickens, and the Lowville and Black river limestones reappear. Prosser's numerous and accurately measured sections, published in the 15th Annual Report of the State Geologist, show that all three are usually present, though occasionally either the Lowville or the Black river is lacking, and the combined formation does not regain any special thickness, being always under 50 feet.

From these facts it is evident that the rather steady, progressive subsiding movement which characterized the region during Beekmantown deposition, and which resulted in the rather constant thickness of that formation of from 450 to 550 feet throughout the Mohawk valley (except where thinned by overlap), was



N. H. Darton, photo.

North bank of creek south of Canajoharie N. Y. exhibiting the relations of the Trenton limestone, horizontal Trenton resting unconformably on slightly folded Beekmantown; the Lowville, Black River and lower Trenton being absent

interrupted at the close of the Beekmantown conditions. There is little evidence that the subsiding movement was changed to one of elevation, except locally about Canajoharie, where it would seem that a slight arching of the surface occurred, accompanied by some slight erosion, before the downward movement was resumed late in the Trenton. Otherwise conditions seem best accounted for on the assumption of a check to the downward movement, which was thence forward in very slight amount for a time, with many small local variations. With cessation of subsidence deposition must soon cease and the evidence of local variations is convincing. The field evidence led the writer to the belief in an unconformity at this horizon, before the search through the literature made him aware that others had brought out evidence along the same line.

### Absence of the Chazy formation in the Mohawk valley

One effect of this pause in subsidence (with perhaps slight accompanying uplift) was to effect an entire separation between the basin of Mohawk valley deposition and that of the Champlain valley, for the time being. In the latter we have a great formation, the Chazy limestone, with a maximum thickness of 800 feet in Clinton county, interposed between the Beekmantown and the Trenton. This formation rapidly diminishes in thickness when followed to the southward in the Champlain valley and wholly disappears before the Mohawk is reached. Its thinning and disappearance seem to be due to a progressively diminishing rate of subsidence toward the south, rather than to overlap. This point will be again reverted to; and, if well taken, it follows that, while a considerable downward movement, progressively greater toward the north, was taking place in the northern district, little or no subsidence, and hence an almost complete interruption of deposition, characterized the southern region during the time interval represented by Chazy deposition.

### Sudden thickening of the Trenton westward

At Trenton Falls the Trenton limestone has a measured thickness of 270 feet, which must be increased by an unknown but small amount, since neither the base nor the summit shows in the section there. At Middleville, 13 miles to the southeast from Trenton Falls, the Trenton is only about 100 feet thick, excluding the passage beds but including the Lowville. From Middleville on to Ingham Mills and thence to Canajoharie, the thinning goes on, but much less rapidly. Now unquestionably a portion of this diminution is due to the interruption of subsidence, this interruption being most pronounced at Canajoharie, thence diminishing both eastward and westward, apparently much more rapidly westward. But the writer is strongly impressed with the possibility, nay probability, that it is in part due to a change in the character of the sedimentation going eastward; in other words that the upper portion of the Trenton of the Trenton Falls section passes laterally, by increase in amount of shale and by disappearance of the few heavy limestone layers, into what are here mapped as passage beds. A large part of the upper half of the Trenton at Trenton Falls, judging from the descriptions of Prosser and White, consists of alternating layers of thin limestone and shale containing few fossils, the whole being capped by the heavy, gray, crystalline limestone at Prospect. With a thinning out and disappearance of this upper heavy layer, very slight change in what lies beneath would give it typical passage zone character, and the gradual downward encroachment of this zone might be very effective in thinning the typical Trenton beneath.

### Comparison with the northern Adirondacks

In the lower Champlain valley, on the New York side, the Paleozoic section comprises the

| | Feet |
|---|---|
| Potsdam formation, maximum thickness unknown but more than | 800 |
| Beekmantown formation, maximum thickness | 1800 |
| Chazy formation, maximum thickness | 800 |
| Trenton (including Black river), thickness unknown, at least | 250 |
| Utica shale, thickness unknown but great | |

This section is at least 3000 feet thicker than that of the Mohawk valley, and likely considerably more, the main part of the excess being in the lower portion of the section. Data as to the slope of the floor on which these rocks were laid down are lacking, though the evidence is clear that it was by no means so even as it is about Little Falls. On the other hand, the surface was by no means so rugged as much of the present Adirondack surface. Yet, with the surface as at present, the thickness of Paleozoic rocks laid down on the north would suffice to blanket the whole region with them, if extended to the south over it. Because of this, the writer has argued in a previous publication that the entire Adirondack region was likely submerged at the close of Utica deposition. Following an entirely different line of argument, Ruedemann has contended for nearly complete submergence *during* the Utica.[1] The evidence on the south seems however somewhat opposed to these conclusions, and at least warrants the statement that any portion of the region which may have remained unsubmerged during or at the close of Utica deposition, was in the southern Adirondacks.

The fact that the deposits of the early Paleozoic are thickest on the northeast, diminishing thence west and south, implies more rapid and more steady subsidence in that part of the region. And the vastly greater quantity of land wash carried into the northern sea indicates that the prevailing drainage of the present Adirondack area was to the north. Along this line may come a propable explanation of the apparently conflicting evidence from the north and the south in regard to the submergence of the district at the close of the Utica.

It seems to argue that the summit of the Adirondack island was toward the southern part of the present region, and if it was not distant more than 30 or 40 miles from the present border it would have become submerged by the close of the Trenton at the estimated rate of overlap.

### TOPOGRAPHY

The present topography of the Little Falls district is the result of, and expression of, its long and complicated geologic history. The pre-Cambrian submergence with its deposits, the pre-Cam-

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[1]Ruedemann, R. Am. Geol. June 1897 and Feb. 1898. p.75.

brian elevation into a land area with its long protracted erosion and its igneous action, the Paleozoic submergence and deposition, and the ensuing and still continuing elevation above sea level, with its erosion, its oscillations of level and its disturbance by faulting, all have their share in the present topography; and, lastly, the recent Glacial period with its advancing and eroding, and its retreating and depositing ice sheets, is entitled to a very large share of responsibility for present conditions.

## Pre-Cambrian surface

Evidence as to the character of the pre-Cambrian surface at the close of the long period of pre-Cambrian erosion, has already been presented, and it has also been shown that it is here more nearly a plane surface than is usual in the Adirondack region. The writer is disposed to regard the more even surface here as representing a plain of marine erosion, more even than on the north, because subsidence was less rapid and of a more intermittent character here, so that the action of the waves was longer continued at a given level.

As the district emerged from the sea after the deposition of the Paleozoic rocks, it appeared in all probability as a coastal plain, with gently sloping, quite even surface. The present pre-Cambrian surface exposures are such because the Paleozoic cover has been removed by later erosion. Along the contact line of today we see the pre-Cambrian surface as it was when originally covered by the later rocks. As we recede from that line, the pre-Cambrian rocks have been exposed to progressively longer wear, during which the less durable rocks have lost more than those of greater durability, and more material has been removed from along the stream courses than from the interstream areas; hence the surface is now one of hill and valley. In regard to this present surface two things seem quite clear, first, that the hilltops rise to quite concordant altitudes, with a general increase in elevation to the northward, and second, that the comparatively plane surface which would be produced by filling up the valleys to the level of the hilltops, does not correspond in inclination with the yet more even surface on which the Paleozoic rocks were laid down. The evidence is in brief as follows:

Examination of the Little Falls topographic sheet shows a progressive rise of the pre-Cambrian hilltops going northward, the highest elevations reached being somewhat over 2000 feet. On the Wilmurt sheet (lying directly north of the Little Falls sheet) the same fairly concordant altitudes are to be noted, and the same slow increase northward, the higher summits in the northern part of that sheet showing elevations slightly over 2500 feet. This is an increase of about 500 feet in 18 miles, or between 25 and 30 feet to the mile. Northward along the western edge of the same sheet the rise is somewhat more rapid, about 50 feet to the mile.

Some idea of the general slope of the pre-Cambrian surface underneath the Paleozoic rocks may be obtained by comparing the altitudes of this surface at Little Falls and at Diamond hill for one line, and from Ilion through Middleville and thence northward for another line.

Diamond hill is 8 miles north of Little Falls. The Spruce creek contact there is at 1200 feet altitude. The pre-Cambrian in the river above Little Falls, taken at that point in order to avoid the lifting effect of the fault as much as possible, is at 400 feet. Thus there is a rise of the pre-Cambrian surface of 800 feet in the 8 miles, or 100 feet to the mile. Since Diamond hill is farther away from the upthrow influence of the fault, this amount is probably a little too small.

In the well at Ilion the pre-Cambrian was reached at 1105 feet, or 700 feet below sea level. At Middleville it is 500 feet above tide, a rise of 1200 feet in between 9 and 10 miles, or about 130 feet to the mile. Ten miles north of Middleville the pre-Cambrian appears from under the Trenton at 1300 feet altitude, a rise of 80 feet to the mile.

While these results are not particularly concordant, and while more data are much to be desired, they do seem to indicate that the one surface falls to the south more rapidly than the other, say from two to three times as rapidly. Both surfaces fall also to the west, but the north-south direction was chosen in order to avoid the tipping produced by faulting, so far as possible.

Since the erosion level whose presence is indicated by the concordant hilltop altitudes does not correspond with the older erosion plane on which the Paleozoic rocks rest, but makes an angle with it, it follows that it must have been developed during a later erosion period. It follows further that the more we recede from the present Paleozoic contact line, the more deeply erosion has cut away the pre-Cambrian rocks.

The area under discussion is so small, and the writer has so little familiarity with the surrounding district, that it would be folly to attempt to trace the erosion level beyond the district, either north or south. That it represents an old level is quite clear, and that it should also be traceable south of the Mohawk is equally clear. The larger portion of the area of the Little Falls sheet has been cut down by later erosion to a lower level. It should be pointed out, however, that the concordant hilltop altitudes, as found here, are also found in the northwestern Adirondacks, but are not to be found on the east and northeast, because of which the writer has argued for recent movements along the fault planes in the latter district as a probable reason for their absence; that is, that the erosion surface was produced there as on the west and south, but that its continuity has been broken by recent differential movements along the old fault planes.

### Present surface of the Paleozoic rocks

As the Little Falls district emerged from the sea after the deposition of the Paleozoic rocks, it presented a low and quite smooth surface, with a gentle inclination to the south or southwest. Since at present the rocks are but slightly tilted from their original nearly horizontal attitude, the original uplift, as well as all others since, has affected their inclination but little. The diagram, figure 13, represents a rude attempt to illustrate the structure of the region on emergence, on the assumption that this took place at the close of deposition of the Medina sandstone of the Upper Silurian. This is in all probability not the case, but the rocks included are all that are now represented in the immediate district, and the diagram is just as suitable for illustrative purposes as if the higher rocks were added. As the district became a land area, streams would extend themselves across it and commence to wear out valleys, tributaries would develop to these main streams, the topography would become more irregular because of this wear, and the precise sort of irregularity developed depended on certain special characteristics of the district. These were the original south slope of the surface, the gentle inclination of the rocks, the variation in resistance of the different formations, and the fact that the Paleozoic cover was thinner at the north than

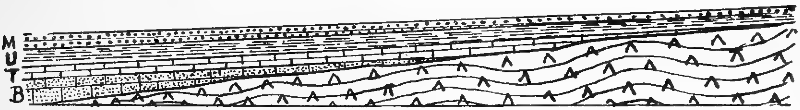



Fig. 13 Diagram to illustrate the condition of the region after deposition of the Paleozoic rocks and emergence above sea level, with smooth, southerly sloping surface B=Beekmantown, T=Trenton, U=Utica and Hudson shales and M=the Oswego and Medina sandstone formations of the Upper Silurian.


Fig. 14 Diagram to illustrate the topography produced as a result of prolonged erosion on the district shown in figure 13. The erosion stage represented is that of greatest possible relief.

at the south. In figure 14 an attempt is made to indicate the character of the surface produced at a certain stage of the erosive process. The Medina is the most resistant of the Paleozoic rocks included, followed in order by the Beekmantown, Trenton and Utica. The Medina would be first cut through by the streams at the north because of its higher altitude there. Once the softer rocks beneath were exposed, erosion would proceed more rapidly. The pre-Cambrian rocks would be first uncovered on the north, both because of higher altitude and because the Paleozoic cover was thinnest there. This slow removal of the Paleozoic cover would then advance southward. The successive Paleozoic formations would then be found infacing toward the old surface on which they were originally deposited. The harder and more resistent layers would inface as lines of cliff, or escarpment, running roughly parallel to the old shore line. Such an escarpment would be specially prominent when the underlying rock was very weak. The resistant Medina sandstone, overlying the weak Hudson shales, forms just such a combination, and the Medina escarpment is a prominent feature of the district south of the Mohawk, though lying beyond the limits of the map.

Since the Beekmantown is more resistant than the Trenton, and that more so than the Utica, erosion tends to strip the Trenton from off the Beekmantown more rapidly than the latter can itself be worn back, and thus to leave a bared strip, or terrace formed on the upper surface of the Beekmantown. For a like reason, a terrace tends also to develop on the upper surface of the Trenton as the Utica is worn away, the level of the Trenton terrace dropping rather abruptly to that of the Beekmantown over the low escarpment formed by the edges of the retreating Trenton layers. Likewise a terrace tends to form on the even pre-Cambrian surface bared by the removal of the Beekmantown, since the former rocks are vastly more resistant.

With the district at a given elevation, wear can be carried on only down to a certain level, determined by the slope necessary to permit the streams to carry away their load of rock waste. The soft rocks will be worn down to this level long before the hard rocks reach it. But then wear ceases on the soft rocks while still continuing on the hard. Therefore features of relief produced by varying rate of wear can reach only a certain degree of accentuation, after which the effect of erosion is to diminish their strength, and, if the region persist sufficiently long at the given level, all rocks, hard as well as soft, will be worn down nearly or quite to the level of the stream bottoms. Renewed uplift will however cause the streams to renew down cutting, again the soft rocks will go down first and the hard again come to stand above their level, resulting in a reproduction of the previous features, the only difference being that they will be shifted to the southward of their position in the previous erosion cycle. The amount of relief obtainable in each cycle will also depend on the amount of uplift.

Now this region has been continuously above sea level for a long time, long enough for erosion to have pared away all rocks, hard as well as soft, down close to base level, and this not only once but more likely several times. That the district is not in this leveled condition but has, well developed, the topographic features outlined above, hard rock escarpments, soft rock valleys and terraces, is in itself indicative of renewed uplift, and that of no very remote date.

There appears also to be evidence that, prior to this uplift, the region had persisted sufficiently long at the previous elevation to have become pretty thoroughly worn down. Such evidence of this as exists in the immediate neighborhood is found in the concordant altitudes of the Adirondack hilltops to the north, and the hard rock plateau summits to the south of the Little Falls sheet. But the district in question is not sufficiently covered by the new maps, nor is the writer's personal acquaintance with it sufficiently extensive to warrant more than the simple statement of his belief that the Cretaceous peneplain, recognized as of wide extent over much of the eastern United States, is recognizable in the southwestern Adirondack region.

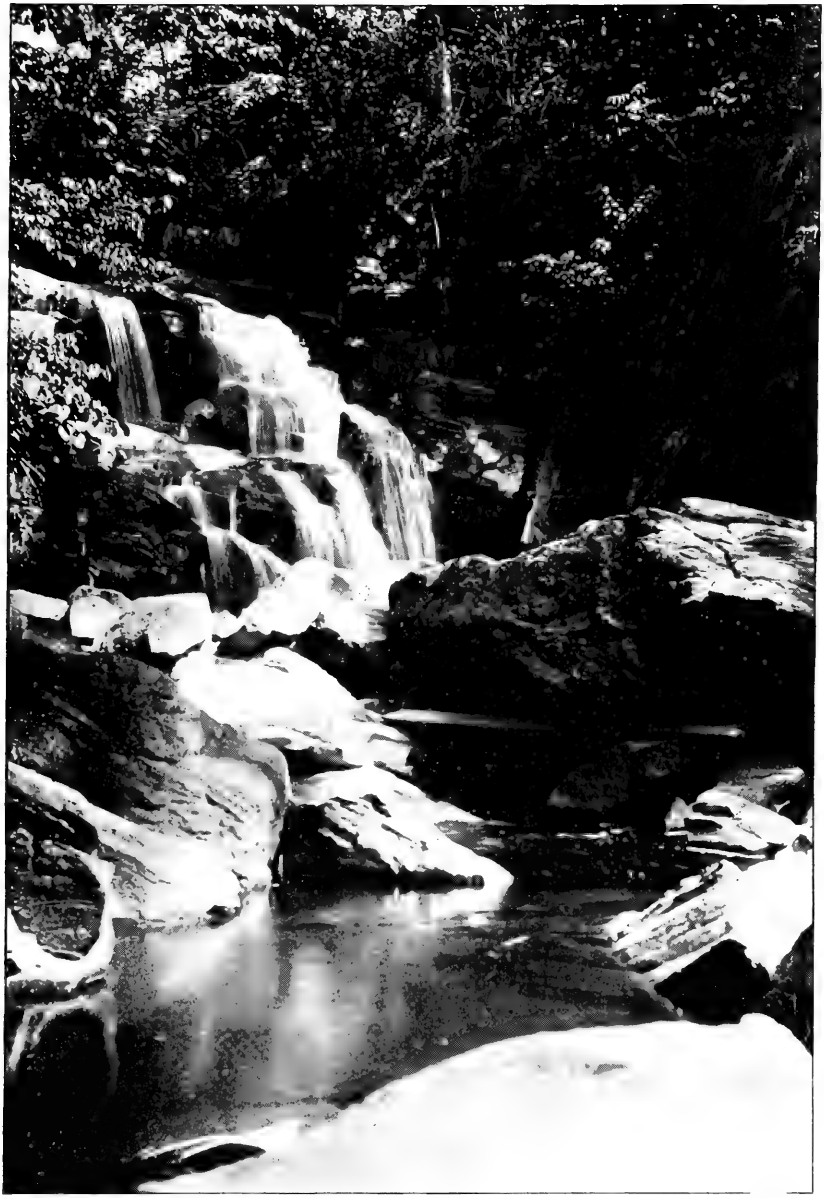
### Influence of the faults on the topography

As newly formed, faults like that at Little Falls produce lines of cliff known as fault scarps along the edge of the upthrown block. Though faulting is a slow process, and though the rising upthrow side is subject to more rapid erosion than the other side because of its greater elevation, so that in all likelihood no fault scarp has ever had a hight equal to the amount of the fault's throw, yet newly formed faults should present scarps whose hight should represent a very respectable percentage of the amount of throw at least.

As time passes, the greater wear on the upthrow side will cut it down to the level of the other and the scarp will cease to exist. It may be made to reappear in one of two ways: first, by renewed faulting taking place along the same line; second, by renewed uplift of the region without faulting. In the latter case the rock on one side at the surface is likely to be more resistant than that on the other, and the more rapid wear in the softer rock will again bring the fault into some prominence as a topographic feature, the amount depending on the difference in resistance of the two rocks concerned, and on the amount of uplift.

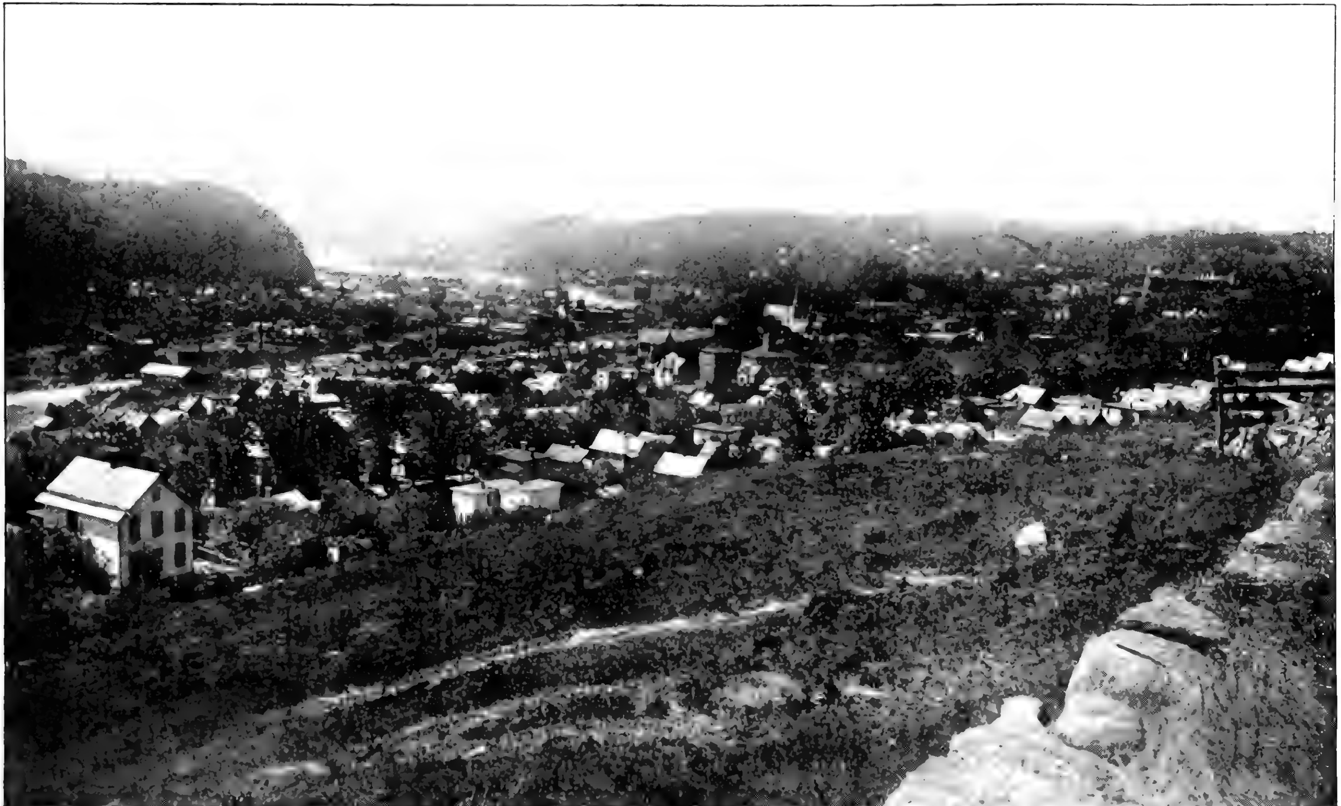
When the faults of the district are examined with these principles in mind, it is at once seen that they are at least sufficiently old, so that the original scarps have been utterly obliterated as topographic features; that no recent slipping has taken place along them; and that such small show as they make in the present topography is due to the rather recent uplift of the region as a whole. The Little Falls fault makes no considerable show in the topography except along the immediate channels of the streams which cross it, all of which show falls or rapids, and gorges below, in the harder rocks of the upthrow side, with sudden change in the character of the valley as the fault line is crossed [*see* pl. 11]. This is most impressively shown along the Mohawk, the broad, mature looking valley developed in the weak Utica shales east of the fault contrasting sharply with the narrow gorge in the resistant rocks west of it, and the fault scarp being a prominent feature when looking up the valley [*see* pl. 12, 13]. Away from the streams, where the fault affects the topography at all, it appears as a low escarpment, with gently sloping instead of steep front, the slope being down the dip of the updragged Utica beds on the downthrow side. Where the very resistant pre-Cambrian rocks are on one side with the Utica shale on the other, the fault is fairly prominent and would be more so were it not for deep drift deposits on the lower side.

The larger faults do, however, have an important indirect effect on the topography. Since they run north-south, and since the uplifting of the west side has given the rocks there a tilt to the westward, in addition to the usual south dip, giving them a local north-south strike, erosion has developed the Beekmantown and Trenton escarpments and terraces there with a north-south trend, at right angles to their usual direction [*see* pl. 14]. The pre-Cambrian terrance is also well developed on the west side of the



H. P. Cushing, photo.

Fall in creek over the pre-Cambrian at the Little Falls fault line 2 miles west of Dolgeville. The creek is in a postglacial valley, and has only cut back its fall 100 yards from the fault plane, the volume being slight and the rocks very resistant. The perpendicular walls of the gorge below are due to the joint planes, and the large loose blocks are dislodged mainly by frost.



N. H. Darton, photo.

Looking up the Mohawk river from the eastern part of Little Falls. Crystalline rocks in bottom of gorge; cliffs of Beekmantown dolomite in foreground; hills of Utica slate in background

H. P. Cushing, photo.

Looking down the Mohawk from the brink of the Little Falls fault scarp, showing the broadly open character of the valley, as contrasted with its narrow character above shown in plate 12. The fault scarp here is prominent and about 200 feet high, but this prominence is only local and due to the nonresistant character of the rock below the fault line, as compared with that above; so that the river has excavated a broad valley in the former while still working at its gorge in the latter.

H. P. Cushing, photo.

Looking down on the Trenton terrace from the Utica shale slope to the west. Taken from a point 4 miles west of Dolgeville, and looking east

Little Falls fault, in the northern part of the sheet. From this standpoint therefore the large faults do yet exert a large influence on the topography in their vicinity.

### PLEISTOCENE (GLACIAL) DEPOSITS

The Pleistocene deposits of the district, and the history which they record, can receive adequate consideration only after a thorough study of a wide area. Brigham has recently published an excellent paper on the "Topography and Glacial Deposits of the Mohawk Valley," containing numerous references to the literature of the subject.[1] The writer has been over such a scant amount of the area that he can add little save some local details to the general discussion.

The amount of glacial erosion in the district does not seem to have been great. The soil and weathered rock were removed and the underlying rock surfaces scoured and polished, but the general topography seems to have been but scantily affected.

Professor Chamberlin has discussed the general ice movement in the Mohawk valley, holding that there was an easterly moving ice tongue in the western portion of the valley, and a westerly moving one in the eastern portion, the two meeting near Little Falls.[2] His final statement sums up as follows:

> I hesitate, at this stage of the inquiry, to encourage any confident opinion in regard to the exact history of glacial movements in the Mohawk valley, further than the general presumption that massive ice currents . . . swept around the Adirondacks and entered the Mohawk valley at either extremity, while a feebler current, at the hight of glaciation, probably passed over the Adirondacks and gave to the whole a southerly trend.

The readings of glacial striae which he reports are quite in accord with this view; and with it the writer's similar observations also agree.

Away from the valley the writer has only two observations on striae, not a sufficient number on which to base any deductions. One mile north of Salisbury Centre striae bearing s. 30° e. were

[1] Geol. Soc. Am. Bul. 9:183-210.

[2] Chamberlin, T. C. United States Geol. Sur. 3d An. Rep't. p.361-65.

observed near the summit of a knoll of pre-Cambrian rock. It is not certain whether the movement was to s. 30° e. or to n. 30° w. though in all probability the former.

Near White creek, 2½ miles north of Middleville, one of the tributary creeks just uncovers, in its bed, the summit of a hill capped by Trenton limestone, on which are plentiful striae bearing n. 80°e. Since this is a hill summit, no rock showing in the banks, and none in the bed either above or below, it should give the general ice direction, and accords well with the records nearer the Mohawk.

The only possible criticism to be made on Professor Chamberlin's quoted statement is that it might lead the reader to hold the view that general glaciation in the Adirondacks was not severe and long continued, and such view is certainly erroneous.

In general, the glacial deposits are not exceedingly bulky over the limits of the sheet, and over much of it they are very thin, the underlying rocks not only outcropping along the streams but repeatedly in the interstream areas. The drift is heaviest in the northwestern part of the district, where the rocks are effectively concealed over many square miles. There is also heavy drift north of Dolgeville.

**Till.** The till varies much in character, the variation being mostly in the rock ingredients, which are mainly of quite local origin, as is usual. In and near the pre-Cambrian area it is rather light colored and excessively sandy, and this is its character throughout the Adirondack region. Elsewhere it is nearly black and much less stony, which is due to its large content of soft, black Utica shale. It seems to acquire large depth only where filling preglacial valleys. The black till is magnificently exposed in the banks of West Canada creek and many of its tributary creeks from the east, often forming perpendicular cliffs up to 100 feet and more in hight. There are also high till banks in Spruce creek north of Dolgeville, and in the creek tributary to East Canada at Ingham Mills. In these the till is overlain by heavy sand deposits, at the base of which large springs issue.

**Moraines.** The heaviest development of morainic accumulation within the map limits is along a line running southeast from the northwest corner to Barto hill and thence eastward through Salisbury Centre to the easterly limits. The moraine is broad on the east and west but narrows in the center. On the east it is associated with a considerable development of kame hills and great overwash sand and gravel terraces. On the west these features are lacking. There is a line of kames to the north of Salisbury Centre, culminating in the "Pinnacle", and to the south of this line a great development of low sand hills and terraces. On the west the kames and sands are lacking, the moraine is associated with heavy till, and, though broad, has no great depth over the till. This moraine would seem the eastward prolongation of the one mentioned by Brigham as blocking the valley at Holland Patent, and the topographic maps seem to indicate that much of its course between is marked by heavy kame sands, as is the case here.[1] West of West Canada creek a heavy moraine appears which would seem to serve as a possible connection between the one above described, and the one described by Chamberlin as coming up to Ilion from the southwest.

**Sands and laminated clays.** Northward and northwestward from Dolgeville is an area of deep sands. Much of it is built into kame hills in association with the moraine. Much however forms flat topped benches with steep sloping fronts. Boulders occur here and there on the surface, though always sparsely. Some gravel is often associated. They lie at all sorts of levels from 800 up to 1500 feet. Their form is often that of delta deposits, but, if such, they represent merely very local and rather rapidly shifting water levels. If the moraine was formed by the shrinking Mohawk glacial lobe, persisting after all ice had disappeared from the foothills to the north, there would be opportunity for the formation of small local lakes along the ice edge, while retreating back from this position, in which the discharging waters of both East Canada and Spruce creeks would build successive

[1] *Op. cit.* p.191.

deltas as the water level fell. It will be an interesting matter to determine if any correlation be possible between these levels and corresponding ones formed by West Canada creek.

South of Dolgeville, and east of the creek, is a sand terrace with summit level of 800 feet, and a line of morainic hills to the east which culminates in the knob just opposite Dolgeville. The sand overlies till, has a depth of from 20 to 40 feet, and seems to be a delta deposit, of East Canada creek in all probability.

The sand and gravel shoulder about Herkimer, with summit at about 600 feet, has been correlated by Brigham with similar deposits farther up the Mohawk valley at the same approximate level, all of which he regards as having been formed in a small lake with water at the 600 foot level, held up partly by ice at Little Falls and partly by the rock barrier there, since trenched by the river.

Below Little Falls is a prominent sand and gravel terrace, with much coarse gravel on the north side of the river, whose summit is between 460 and 480 feet. It is found on both sides of the river, though most extensively and least interrupted on the north. Though slightly higher, these levels are quite concordant with those of the similar deposits described by Brigham as extending from East Creek (just beyond the map limits on the east) down to Amsterdam, at about the 440 foot level, and regarded by him as indicating static water at that level, held up by some as yet unknown barrier at or below Amsterdam.

At several localities finely laminated, plainly water-laid clays, nearly or quite destitute of pebbles, were noted. They seem of necessity to mark static water conditions, yet are at such varying altitudes, and run up to such high levels, that they can be attributed only to a series of wholly independent and very local water bodies.

Just west of Dolgeville is a flat topped, steep fronted sand and gravel terrace with a summit elevation of 840 feet. One and one half miles north of Dolgeville, on the divide between Spruce and Cold creeks, are finely laminated clays at 900 feet. The lamination is so fine and even that the material was mistaken for weathered Utica shale before it was closely examined. To the north, and overlying this, is a sloping sand terrace at from 1000 to 1040 feet, followed to the north by the heavy sand hills of the kame moraine. The whole combination seems to indicate a local obstruction of the drainage coming down from the north by the ice lobe, as it was retreating south from the position of the moraine, forming a small lake in which the clay was laid down, on top of which the streams thrust out a delta. Further retreat permitted the formation of the lower delta near Dolgeville.

Still farther north, the "Pinnacle" kame sands are seen to lie on a similar laminated clay, which there is at 1200 feet. In the single exposure seen the dip is at first nearly flat and then rapidly changes to one of 45° to n. 50° w., suggesting a possible disturbance by the ice, in which case the clay would antedate the last ice advance.

In the tributary to Crum creek at Manheim Center, at an elevation of 520 feet, is a laminated, fine clay with occasional minute pebbles. It lies too high for association with the 440 foot water level, and seemingly too far east to have any relationship with the 600 foot level west of Little Falls. It shows no associated sands, and appears to be overlain by morainic accumulations, in which case it also must have been laid down prior to the last advance of the ice.

But whether these different clays are older or younger than the time of last ice advance, their great variation in altitude affords a difficult matter for explanation, and seems to the writer to indicate small water bodies produced by extremely local conditions.

**Drainage.** Brigham has sketched an outline of the drainage development of the district in preglacial times, with which the writer is in full accord and to which he can add nothing. To this, those interested are referred.[1]

Just before the onset of the ice, the drainage of the district consisted of the main, east-west trunk valley, worn out along the belt of weak rocks under the Medina, into which came tributary streams from the north and south, the whole constituting a well developed drainage network which had carved prominent valleys.

[1] *Op. cit.* p.184-92.

The main valley was only partially filled by glacial deposits, and was reoccupied as the main drainage channel on the retreat of the ice. The main change effected was the shifting of the position of the divide between the easterly flowing stream in one, and the westerly moving drainage in the other end of the valley. The present divide is at Rome, is of the most trivial description and is composed of glacial deposits which manifestly could not have formed a preglacial divide. The preglacial col was in all probability at Little Falls, as urged by both Chamberlin and Brigham. Here the valley is narrowest, here is the most resistant rock mass anywhere in the valley, brought up on the west side of the fault, and here the drainage adjustment of the long, preceding time of wear would inevitably locate the divide.

After the ice had disappeared from the Mohawk valley but was still blocking that of the St Lawrence, the waters of the Great lakes went to the sea by the Mohawk valley route, and this great rush of water must have been very efficient in cutting away the rock obstruction at Little Falls. On the other hand, it is obvious that at this time the divide could by no means have had the hight of the present valley walls, nor even that of the pre-Cambrian surface at the fault line (600 feet), the latter being more than 100 feet above the present divide at Rome. Chamberlin has suggested that the outer and wider gorge at Little Falls was cut during interglacial times, and this is very probable; at all events, it is certain that the inner gorge represents the total amount of cutting since the ice retreat. This interglacial erosion of the col, together with the heavy drift deposition about Rome, shifted the divide to that point, so that between the two points there is now easterly, where formerly was westerly, flowing drainage.

Brigham has argued that the preglacial course of West Canada creek was by way of Holland Patent, where now is a broad, open valley occupied by a small stream. Certain it is that from Prospect to its mouth the stream is not in its old channel, and that from Prospect to below Trenton Falls it is not in an old channel of any sort.

From Middleville to Herkimer the course of a small preglacial stream is apparently followed, whose source was at Middleville,

D. McBride, photo.

View on East Canada creek ½ mile above Dolgeville, where its course is through a drift-filled valley. Compare with plates 6-9.

where there was in all likelihood a minor divide, located by the more resistant rocks domed up there. This col must also have been cut down in glacial times and quite probably by glacial erosion at a time when the full current of ice swept over the Adirondacks. Though constricted, the valley is not a gorge at Middleville, is U-shaped, there is neither fall nor rapid in the stream, and the knobs of pre-Cambrian rock near the creek level show unmistakable evidence of glacial wear. Just above Middleville, too, the valley is heavily clogged with drift to below the creek level, and even immediately below the town, where the valley is narrowest, till descends in places to the stream level.

East Canada creek also, so far as it lies within the map limits, is not in its old valley, though where that was can only be conjectured. From Dolgeville to the fault line it is in a wholly postglacial valley, with rapids, and a high fall with a gorge below. Below the fault the stream enters the east side of a preglacial valley, which lies to the west of its present course, and out of which it turns into the modern gorge above Ingham Mills. For a mile below Ingham it apparently crosses another preglacial valley, nothing but drift showing in the banks and bed, and begins to disclose rock again in the bed just before leaving the sheet, beyond which it has cut another rock gorge.

North of Dolgeville the stream is in a preglacial valley, out of which it turns at the big bend to the east [*see* pl. 15, and compare with pl. 6, 7, 8, 9]. To the northward along this line there is heavy drift, with no rock showing, for some miles; and on the prolongation of the same line to the south no rock exposures occur over a belt at least a mile in width, all the way to the Mohawk. The course of a preglacial valley, rather closely following the Little Falls fault line and lying between that and the present valley of East Canada creek, is thus rendered probable, and such a valley would also seem likely on structural grounds, adjusted to the belt of weak Utica shales between the Little Falls and Dolgeville faults.

The smaller tributary creeks all show the same general features; here they develop rapids, falls and gorges; above and below they show nothing but heavy drift in banks and bed. Their present courses were determined by the contours of the deposits left by the retreating ice sheet, and do not correspond with the old valleys in position but cross them at varying angles. The present rock-bound portions of their courses are due to the uncovering of hill-tops and divide summits of the preglacial topography, which lay buried beneath their modern courses when they first assumed them. When they occupy, or cross, old valleys, they have not yet been able to cut down to their rock bottoms and have only partially removed the drift filling. The modern valleys are not as large, as deep, nor as mature, and the surface relief is not as great as before the appearance of the ice.

Spruce creek presents some interesting features. All the upper part of its course closely follows the pre-Cambrian edge. This contact forms a natural drainage line because of the southwesterly slope of the resistant pre-Cambrian surface uncovered by the retreat of the Beekmantown inface, and there must certainly have been a preglacial stream here. Brigham has noted the corresponding position of Black river, which follows this contact for miles.[1] The present divide between Spruce creek and Black creek (an affluent of West Canada creek which flows to the northwest along the contact line) is a moraine ridge near the north limit of the sheet. Both these streams are in their old valleys, though where the preglacial divide was is uncertain, the writer however suspecting that it was at or near Diamond hill, and that the present upper part of Spruce creek is in the old Black creek valley, the drainage now being reversed. However that may be, the gorge at Diamond hill is modern, either because of the cutting down of a col, or because the stream is there turned aside out of its old valley. Just below, the valley is blocked by a moraine, and to the eastward of the gorge no rock shows at the surface for a mile, so that we are not limited to the supposition of a col at this point to explain the present course of the stream. From Diamond hill to the fault line the stream is occasionally out of the old valley, specially at Salisbury Center, thence its course to its mouth is

[1] *Op. cit.* p.186.

through the drift of the old, deeply filled valley east of the fault line. There is no wide outlet valley into this through which the preglacial Spruce creek could have come, and there must have been once a col at the fault line, but this would have been cut back, and the narrowness of the old valley would seem due simply to the great hardness of the pre-Cambrian rocks in which it was cut.

The heavy drift filling for several miles east of the fault line, as contrasted with the abundant rock outcrops on the west side, shows that in preglacial times the fault was a more conspicuous topographic feature than is the case now, and this by an amount measured by the unknown thickness of the drift over the rock on the east side.

These old, buried valleys introduce an element of uncertainty into the areal mapping of the rocks. For the most part they must be ignored, since their location is unknown; and, where they have been located, the depth of drift is unknown, so that the precise rock horizon beneath can not be told. Whenever they exist, the areal map is likely to be somewhat in error in regard to the surface rock.

## ECONOMIC GEOLOGY

**Building stone.** The Lowville limestone has been the main quarry rock of the district, and has had a considerable local use. It is in general quite massive, not excessively jointed, of pleasing color and quite durable. It has been more largely quarried at Ingham Mills than at any other locality, though several other quarries have been opened, the location of the principal ones being shown on the areal map. The big Dolge mills at Dolgeville are constructed of it, the locks of the Erie canal also and many other smaller structures. It makes a most excellent building stone, admirably fitted to supply all local necessities of the sort. It has also been somewhat burned for lime and would seem the most suitable of the local rocks for the purpose.

The Beekmantown rocks have been somewhat quarried at Little Falls, the lower layers being used, and slight openings have been made elsewhere. While not as good as stone as the Lowville, this rock has had considerable use at Little Falls for purposes for which stone of inferior quality answers equally well, since it costs less than the other at Little Falls, because of its nearness.

The syenite has also been quarried for building stone near Little Falls. It supplies only a local use and mainly for rough work. The excessive jointing is a defect, in that very large blocks can not be procured, but, on the other hand, it vastly diminishes the expense of quarrying. The stone is for many purposes an excellent one, much of it is of good quality, the supply is ample for all local use, and, since it is the only locality in the valley where a crystalline rock suitable for building purposes occurs, a future demand for it will inevitably arise.

**Road metal.** There is an inexhahustible amount of good road material to be obtained within the area covered by the map, and, as road improvement is likely to be a matter of the near future, this is a fact of considerable importance. The pre-Cambrian rocks furnish the best material, but the Lowville and Trenton limestones also afford excellent stone for the purpose.

The big diabase dike which cuts the syenite just east of Little Falls on the north side of the river, is the best source of road metal in the district from the standpoint of quality, and, since the dike is over 100 feet wide, the amount available is not small. Since also the adjacent syenite is nearly as well adapted to the purpose as the diabase, there need be no careful separation of the two in working out the material at the edge of the dike.

Next to the diabase the syenite is the best road metal rock in the district. Near the depot at Little Falls the syenite is all cut up by a fine grained, red rock of granitic make-up (an aplite), which is so rich in quartz as to be a rather poor road rock. But the cliffs to the eastward show but little of this rock, so that there is a large quantity of excellent and easily accessible material.

The rock at Middleville would be equally good for the purpose, but the quantity in sight above the level of the creek is very small.

Much of the pre-Cambrian rock to the north would also serve the purpose well. The syenite gneiss is best, while the red granite gneiss and the light colored, Grenville quartz gneisses are not well adapted and should not be used.

Next to the pre-Cambrian rocks the black, slaty limestones of the passage beds afford the best road material, and have already been somewhat used for the purpose in the district. The main objection to their use is expense in quarrying, since the shale partings must be rejected, and these constitute half the bulk of the rock.

Both the Lowville and Trenton limestones will furnish an acceptable road metal, the former better than the latter. The Beekmantown rocks are in general too sandy, and much inferior to any of the foregoing.

The advantage of the pre-Cambrian rocks over the limestones is in their superior durability, along with sufficiently good binding power. But the work must be done with much more care in order to produce satisfactory results, and where this can not be done, the limestone is the preferable material.

**Clays.** Use has been made of the clays in but one locality, A. C. Kayser manufacturing brick from a clay bed just out of Dolgeville to the west.[1] There would seem no good reason why an excellent quality of common brick, and tile also, should not be manufactured from the laminated clays in several localities, provided exploitation shows the clay present in sufficient quantity, as is in all likelihood the case.

**Sand and gravel.** There is a great abundance of both these materials for all possible uses, both in the Mohawk valley and also along the line of the great moraine which follows rather closely the pre-Cambrian boundary.

**Salisbury iron mine.** The only locality within the sheet limits at which iron ore has been found in anything like workable quantity, is at the above mine, 2 miles north of Salisbury Center. Considerable ore has been obtained at this location, some quite

[1] Ries, H. N. Y. State Mus. Bul. 35, p.713.

recently. But at the time of the writer's visit work was not in progress and no very satisfactory observations could be made.[1] The working is in the nature of a pit with a maximum depth of some 80 feet, the sides are perpendicular, there was some 20 feet of water at the bottom, and adjacent surface exposures are of the most meager description, so that information must be sought from either the inaccessible sides of the pit, or else from the dumps.

The main pit is from 25 to 30 yards long, from 3 to 4 yards wide, and bears nearly east and west. The dip is to the south and very steep, some 75° to 80°. The pay streak was evidently lens-shaped, pinching out at the two ends of the pit, and nothing could be learned regarding its exact size, or the purity of the ore. To the west no rock shows in outcrop, but to the east, after a 10 yard gap with no exposures but in which the ore had evidently pinched out, is another opening showing a much narrower ore body, beginning with a width of 6 inches and widening to 3 feet. Apparently mining here was never profitable, as the opening is very shallow. At the extreme east end the ore again pinches out and beyond occurs only in small, interrupted masses.

Practically the only rock outcrops are those of the vertical walls of the pit. Little pure ore was found on the dumps, but much lean ore was there, consisting largely of what must have been the immediate wall rock, a very basic hornblende gneiss. This is found to pass into a gneissoid syenite, all intermediate gradations being found. The syenite shows a local phase characterized by abundant mica (biotite) which is unlike any other rock of the district. The ordinary syenite passes into a very quartzose syenite, which is full of quartz and pegmatite veins.

A short distance north of the main pit is a low rock knoll, exposing a well banded, rusty gneiss, full of quartz veins, from which no fresh material could be obtained, and whose precise nature is uncertain, though it much resembles the acid phase of the syenite mentioned above. Near the narrow opening a basic,

[1] Since then, some farther exploitation has been done but no opportunity to revisit has occurred

garnetiferous gneiss outcrops, whose relationships are also uncertain.

One quarter mile to the eastward, along the strike, are outcrops of apparent syenite gneiss, but just north, massive ridges of Grenville gneisses cut it out, and just south are granites and dubious gneisses which are certainly not referable to the syenite, so that we are dealing here with an exceedingly small syenite intrusion, if it really be that rock.

The ore itself is of the platy sort, rather than of the granular crystalline character of much of the magnetite of the eastern Adirondacks. In this respect it is like much of the Franklin county ore. Now, while the writer has had no opportunity carefully to investigate these ores, the small study that he has been able to give them leads to the belief that many of them are of igneous origin, being basic segregations from the syenite magna, just as the titaniferous magnetites are segregations from the anorthosite. But, whereas ores of the sort are quite customarily developed in gabbro intrusions, they have been seldom noted in syenites, so that the matter requires thorough investigation, and the statement of origin is only tentatively advanced. The Salisbury ore also seems to fall into the same class, but, because of the poor exposures and the very small size of the mass of apparent syenite, the writer rather hesitates to advance the idea, though himself rather confident of its verity. If the mass be a result of differentiation in an intrusive, it is remarkable, not only because of the kind of rock involved, but also because of the great amount of differentiation in a very small eruptive mass. The thin sections seem to bear out the idea of the igneous nature of the whole, as will be shown later.

## PETROGRAPHY OF THE PRE-CAMBRIAN ROCKS

**Grenville rocks.** These are old aqueous rocks which have been so excessively metamorphosed as to have become entirely recrystallized, with loss of all original structures, so that the main argument for their origin is that based on composition. As occurring in the district, they consisted mainly of shales and shaly sandstones, limestone being absent. These are now gneisses of various colors, from white to black, nearly always containing pink garnets, and with the darker varieties often holding graphite as well.

What are supposed to have been shaly sandstones are now white to gray, or greenish gray, gneisses, which are rather well banded, thus hinting at a sedimentary structure due to variation in composition of different layers. If this banding does represent original bedding, then the present foliation conforms in direction with it.

To the eye these light colored gneisses appear very quartzose, but the microscope dispels the impression. No case has been observed in which the quartz constitutes so much as 50% of the rock. It commonly runs from 30% to 40%, seeming always somewhat subordinate to the feldspar in amount, the ratio between the two varying from 3 : 5 to 4 : 5. Most of the feldspar appears to be anorthoclase, as indicated by its faintly moiré appearance, but often a very considerable percentage of an acid plagioclase (apparently between albite and oligoclase) is present in addition. Other minerals than quartz and feldspar seldom constitute as much as 10% of the rock and often fall below 5%. Minute zircons usually occur in considerable number, so much so as to form a prominent feature of these Grenville rocks. Small garnets are frequent. A little biotite, a little magnetite and an occasional titanite are the other customary minerals. The silica percentage must lie above 75% in all cases, and it is believed that chemical analyses would point strongly toward a sedimentary origin for the rock, as suggested by its mineralogy and appearance.

These quartzose gneisses contain bands of somewhat more basic character, which differ from them mainly in the larger content of garnet and biotite, and in usually holding graphite in addition, mostly in minute scales and in no great quantity. One large garnet was noted full of inclusions of a green spinel, probably pleonaste. The minerals other than quartz and feldspar make from 15% to 20% of the rock. The quartz percentage is nearly or quite as high as in the more acid gneisses, the basic minerals increasing at the expense of the feldspar.

There is also much of a more basic, heavily garnetiferous rock interbanded with the lighter colored one. Its mineralogy is much the same as that of the white gneisses in respect to the minerals present, but there is a great change in quantity. There are the same abundant small zircons, quite a little graphite, pyrite and apatite are present, a little magnetite, quite a lot of biotite and abundant garnet. All together these make from 30% to 50% of the rock, garnet alone constituting from 20 to 30%. The remainder of the rock is made up of feldspar, nearly all of which is microperthite, only a little acid plagioclase being present. The rock is practically free from quartz, all there is being found as inclusions in the large garnets. It would seem to have the composition of a calcareous shale, yet is not at all the sort of rock customarily produced from such shales by metamorphism, as amphibole of some sort usually develops in quantity. In fact, the rock may not have been calcareous, since, if present, the lime is now in the garnet, and it has not been analyzed. If it be a lime garnet the deep seated conditions prevailing during metamorphism may account for the character of the rock.

There is another variety of the above rocks which is characterized by abundant pyrite, roughly some 5%. It also has a considerable quartz content, some 25%, and more than half of the feldspar is plagioclase, an acid oligoclase with maximum extinctions of 10°. There is also considerable of a thoroughly rotted bisilicate. Biotite is present in large quantity and garnets are sparing or absent. With pyrite decay the rock weathers rusty. All sorts of gradations between all these types occur, but taken as a whole they characterize the sedimentary Grenville of the district.

Along with the foregoing are occasional bands of a rusty weathering gneiss which, when fresh, is seen to be thoroughly gneissoid, foliae of glassy quartz grains alternating with black leaves of more basic mineral fragments, the whole making a rather dark colored rock. Yet it shows a higher quartz content than any other, that mineral making fully two thirds of the rock. It is of coarse grain but not of the leaf type, and holds a multitude of inclusions of the other minerals, along with a little apatite and many zircons. Except for these inclusions the quartz foliae are entirely of that mineral.

Between is a mosaic of garnet, augite, bronzite and feldspar, with many minute graphite scales. Oligoclase is the prevailing feldspar, though with anorthoclase also. Notwithstanding the high quartz content, the rock holds more lime and magnesia than any of those already mentioned and would seem to have been a calcareous sandstone. It grades into less quartzose varieties.

**Associated igneous gneisses.** Mingled with the Grenville sediments, often intricately, are other gneisses, some of doubtful, and some of pretty distinctly igneous character. These rocks are always thoroughly gneissoid, retaining no more trace of their original texture than is the case with the old sediments, so that again the argument for their origin is mainly based on their composition. The dubious rocks are of so many sorts and shades that it is difficult to treat of them except in a mass of details which would be out of place here. Some of them may likely be foliated contact rocks, and others may be due to a development of mixed rocks along the contacts of the aqueous and igneous rocks by an interchange of materials during metamorphism, though it is not at all certain that such transference ever takes place to any important extent, even during very deep seated metamorphism.

The probable igneous rocks show a range from the most acid granites through syenitic rocks to heavy, black rocks of gabbroic composition.

The granitic gneisses are usually of red color and mainly composed of quartz and feldspar, the gneissoid character being dependent on the development of quartz of the leaf type in thin foliae, separated by fine quartz feldspar mosaic. The quartz makes from one quarter to one half of the rock, the feldspar is mainly anorthoclase or microperthite, though with some oligoclase always, and sometimes a little microcline, and the other constituents are small amounts of zircon, apatite, magnetite and biotite, with sometimes hornblende also. These taken together often constitute no more than 5% of the rock, and seldom exceed 10%. There are occasional coarser feldspar fragments present which may represent crystal remnants of the original rock that have escaped the prevailing recrystallization.

The syenites are gray to greenish gray rocks, commonly rather quartzose, which approach granites on the one hand and gabbros on the other. Except for their close association with the Grenville sediments, they are not to be distinguished from the thoroughly gneissoid phases of the later syenite, whose description will serve equally for them.

The original gabbros are now converted into hornblende or pyroxene gneisses. On the one hand, are hornblende, biotite, plagioclase gneisses; on the other, augite and bronzite (or hypersthene) appear instead of hornblende. In the pyroxene gneisses garnet often occurs, magnetite always and pyrite sometimes. The feldspar ranges from andesin to labradorite; but not infrequently a large part of it is not plagioclase at all but of intergrowths, either of microperthitic or of micrographic habit, and such portion may make more than 50% of the whole, giving the rock more of a monzonitic than of a gabbroic make-up.

**Syenite gneiss.** The area given the syenite coloration in the northeast portion of the geologic map is constituted of quite homogeneous rocks, of thoroughly gneissoid character, gray to greenish gray color, rapidly weathering brown, and of syenitic make-up. They vary somewhat in coarseness of grain and considerably in their quartz percentage, some of them being very acid. There are occasionally to be seen slightly larger feldspar fragments which seem to be of the nature of augen, and around which traces of cataclastic structure appear. But these are small fragments at best, the structure traces are obscure, and the evidence of igneous origin from this standpoint very slender. If, however, the writer be correct in referring the augen character of the syenite at Little Falls to an original porphyritic structure in the rock, then the absence of that character here may have no further significance than to denote the original lack of that structure.

The rock is composed of quartz and feldspar with varying amounts of biotite, augite, bronzite and hornblende, and with magnetite, apatite, zircon, and a little occasional titanite as accessories.

The quartz content ranges from 5% to 25%. It is evidently all recrystallized and commonly of coarser grain than the other minerals, though never prominently of the leaf type. Its increase in amount is accompanied by diminution of the dark silicate content, specially of the augite and bronzite.

Feldspar makes from 65% to 85% of the rock. It is mostly of faintly moiré appearance, seldom well marked microperthite, and is presumably anorthoclase. But some oligoclase is always present as well, usually in small amount, but rising to as high as 25% of all feldspar present. The mineral is usually in equidimensional grains, constituting a fine mosaic, and, except for an occasional larger individual with traces of cataclastic structure, seems to have been wholly recrystallized. The larger fragments are usually of well marked microperthite.

Biotite is the most constant of the dark silicates, occurring in nearly all varieties of the rock, and being practically the only one to persist in the more acid varieties. Bronzite is perhaps next in abundance. Sometimes all four (bronzite, augite, hornblende and biotite) are present, and then biotite plays a subordinate role. Including magnetite these minerals never make more than 15% of the rock, and in the quartzose members may fall below 5%.

**Rocks at the Salisbury iron mine.** *Ore.* The thin section of the purest ore which the writer could find on the dumps shows the presence of many inclusions of other minerals, though indicating that these are not present to the amount of more than 15% to 20%, and hence that the ore is rich, though there is nothing to show how large a proportion has this character. Professor E. W. Morley was so good as to make a test of the ore for titanium, his result proving that the ore is not titaniferous to any appreciable extent, the figures being certainly under .5%.

The inclusions are of apatite, augite and quartz. The two former are numerous, though rather small, have good idiomorphic boundaries against the magnetite, specially in the case of the apatite, which clearly formed before the magnetite, as did apparently some of the smaller augites also. The augite is of pale green color, without pleochroism, exactly like that of the wall rock.

The quartz inclusions are of much interest. They are of the elongated leaf or spindle shape, like the quartz of the inclosing gneisses, and some of them are of large size. Polarized light shows that they are composed of a much greater number of separate mineral fragments than usual, and all show strong undulatory extinction. Around many of them is a zone, or rim, of finely crystalline augite. These rims are also duplicated in some of the inclosing gneisses and seem clearly due to reaction between the magnetite and quartz. In the gneisses they only form between magnetite and quartz. They are exceedingly like the augite rims which form about quartz inclosures in basic igneous rocks. Why they do not occur about all the quartzes is a puzzle. The writer is disposed to regard the presence of the quartz in the ore as due to metamorphism and attendant recrystallization, whence it would follow that the rims formed as a result of the same process.

*Walls.* Inclosing the ore, and grading into it, is a very basic gneiss composed of hornblende, magnetite, augite, feldspar and quartz, the black minerals constituting 75% of the rock. Hornblende is much the most abundant of these. About equal amounts of quartz and feldspar are present, the feldspar being part oligoclase and part anorthoclase.

So far as can be judged from specimens obtained from the dumps, this gneiss grades rapidly into a more feldspathic hornblende gneiss, and the latter into a syenite gneiss, at first basic but rapidly becoming more acid.

The more basic rock shows abundance of fairly coarse hypersthene, which is platy, lies in the foliation planes, gives the rock a green and black mottled aspect, and seems certainly secondary and formed during metamorphism. There is considerable magnetite in the rock, which shows augite rims wherever it is in contact with quartz and also around the small quartz inclusions. A little biotite and green hornblende are present, and considerable apatite, the latter often of large size and full of black, dustlike inclusions. The feldspar is mostly anorthoclase, though quite a bit of oligoclase is present. There are some larger feldspars which seem to have escaped recrystallization, and these are microperthite. Quartz is but sparingly present, mostly in coarse leaves, though also as inclusions in the coarse hypersthenes and magnetites. It is present to the amount of some 5% only, while feldspar constitutes from 65% to 70%.

The rock seems to be igneous and to be a syenite, though with peculiarities. Except for some possible small amounts of feldspar, magnetite and apatite, it seems to have undergone complete recrystallization. In many respects, notably in the augite rims, it is peculiar and affiliated with the ore.

The last rock of the series strongly resembles the acid variety of the ordinary syenite gneiss of the region. It is mainly a feldspar quartz rock. In addition are numerous small zircons and a little apatite, biotite, magnetite and hornblende, all together not constituting over 5% of rock. The feldspar is mostly anorthoclase, though with a little oligoclase in addition. The quartz forms some 20% of the rock and is mainly in rather coarse leaves. The rock is wholly recrystallized, but has syenite composition.

We seem here to be clearly dealing with a basic segregation in a rather acid rock of probable igneous origin. But the exposures are so poor, and the whole series so metamorphosed that no decisive evidence is forthcoming in regard to the origin of the ore. While it seems not unlikely that it may represent an original basic segregation from the cooling intrusive, analogous to the titaniferous ores of the gabbroic intrusives of the region, the evidence is far too meagre to warrant a definite pronouncement in favor of this mode of origin. The ore may equally as well owe its existence to secondary processes.

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The superior figures tell the exact place on the page in ninths; e. g. $87^3$ means page 87 beginning in the third ninth of the page, i. e. about one third of the way down.

*University of the State of New York*

# New York State Museum

## PUBLICATIONS

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**Museum annual reports** 1847-date. *All in print to 1892, 50c a volume, 75c in cloth; 1892-date, 75c, cloth.*

These reports are made up of the reports of the director, geologist, paleontologist, botanist and entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

**Geologist's annual reports** 1881-date. Rep'ts 1, 3-13, 17-date, O; 2, 14-16, Q.

The annual reports of the early natural history survey, 1837-41, are out of print.

Reports 1-4, 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 following museum reports, except that certain lithographic plates in the 11th report (1891) and 13th (1893) are omitted from the 45th and 47th museum reports.

Separate volumes of the following only are available.

| *Report* | *Price* | *Report* | *Price* | *Report* | *Price* |
|---|---|---|---|---|---|
| 12 (1892) | $.50 | 17 | $.75 | 21 | $.40 |
| 14 | .75 | 18 | .75 | 22 | .40 |
| 15, 2v. | 2 | 19 | .40 | 23 | *In press* |
| 16 | 1 | 20 | .50 | | |

In 1898 the paleontologic work of the State was made distinct from the geologic and was reported separately from 1899-1903. The two departments were reunited in 1904.

**Paleontologist's annual reports** 1899-date.

*See* fourth 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. Since 1901 these reports have been issued as bulletins.

**Entomologist's annual reports** on the injurious and other insects of the State of New York 1882-date.

Reports 3-19 bound also with museum reports 40-46, 48-57 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3-4 are out of print, other reports with prices are:

| *Report* | *Price* | *Report* | *Price* | *Report* | *Price* |
|---|---|---|---|---|---|
| 1 | $.50 | 9 | $.25 | 15 (En. 9) | $.15 |
| 2 | .30 | 10 | .35 | 16 ( " 10) | .25 |
| 5 | .25 | 11 | .25 | 17 ( " 14) | .30 |
| 6 | .15 | 12 | .25 | 18 ( " 17) | .20 |
| 7 | .20 | 13 | .10 | 19 ( " 21) | .15 |
| 8 | .25 | 14 (En 5) | .20 | | |

Reports 2, 8-12 may also be obtained bound separately in cloth at 25c in addition to the price given above.

**Botanist's annual reports** 1867-date.

Bound also with museum reports 21-date 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 25-28, 30, 42-50 and 52 (Botany bulletin 3), are out of print. Report 51 may be had for 40c; 53 for 20c; 54 for 50c. Since the 55th these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have been published in volumes 1 and 3 of the 48th museum report and in volume 1 of the 49th, 51st, 52d, 54th and 55th 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. O. *To advance subscribers, $2 a year or 50c a year for those of any one division:* (1) *geology, economic geology, mineralogy, general zoology, archeology and miscellaneous,* (2) *paleontology,* (3) *botany,* (4) *entomology.*

Bulletins are also found with the annual reports of the museum as follows:

| *Bulletin* | *Report* | *Bulletin* | *Report* | *Bulletin* | *Report* | *Bulletin* | *Report* |
|---|---|---|---|---|---|---|---|
| G 1 | 48, v.1 | Pa 1 | 54, v.1 | En 7-9 | 53, v.1 | Ar 3 | 52, v.1 |
| 2 | 51, v.1 | 2, 3 | " v.3 | 10 | 54, v.2 | 4 | 54, v.1 |
| 3 | 52, v.1 | 4 | " v.4 | 11 | " v.3 | 5 | " v.3 |
| 4 | 54, v.4 | 5, 6 | 55, v.1 | 12, 13 | " v.4 | 6 | 55, v.1 |
| 5 | 56, v.1 | 7-9 | 56, v.2 | 14 | 55, v.1 | 7 | 56, v.4 |
| Eg 5, 6 | 48, v.1 | Z 3 | 53, v.1 | 15-18 | 56, v.3 | Ms 1, 2 | " v.4 |
| 7 | 50, v.1 | 4 | 54, v.1 | Bo 3 | 52, v.1 | | |
| 8 | 53, v.1 | 5-7 | 54, v.3 | 4 | 53, v.1 | Memoir | |
| 9 | 54, v.2 | 8 | 55, v.1 | 5 | 55, v.1 | 2 | 49, v.3 |
| 10 | " v.3 | 9 | 56, v.3 | 6 | 56, v.4 | 3, 4 | 53, v.2 |
| 11 | 56, v.1 | En 3 | 47, v.1 | Ar 1 | 50, v.1 | | |
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NEW YORK
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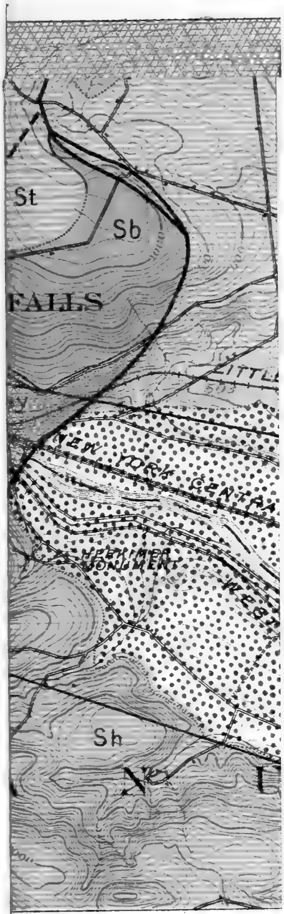


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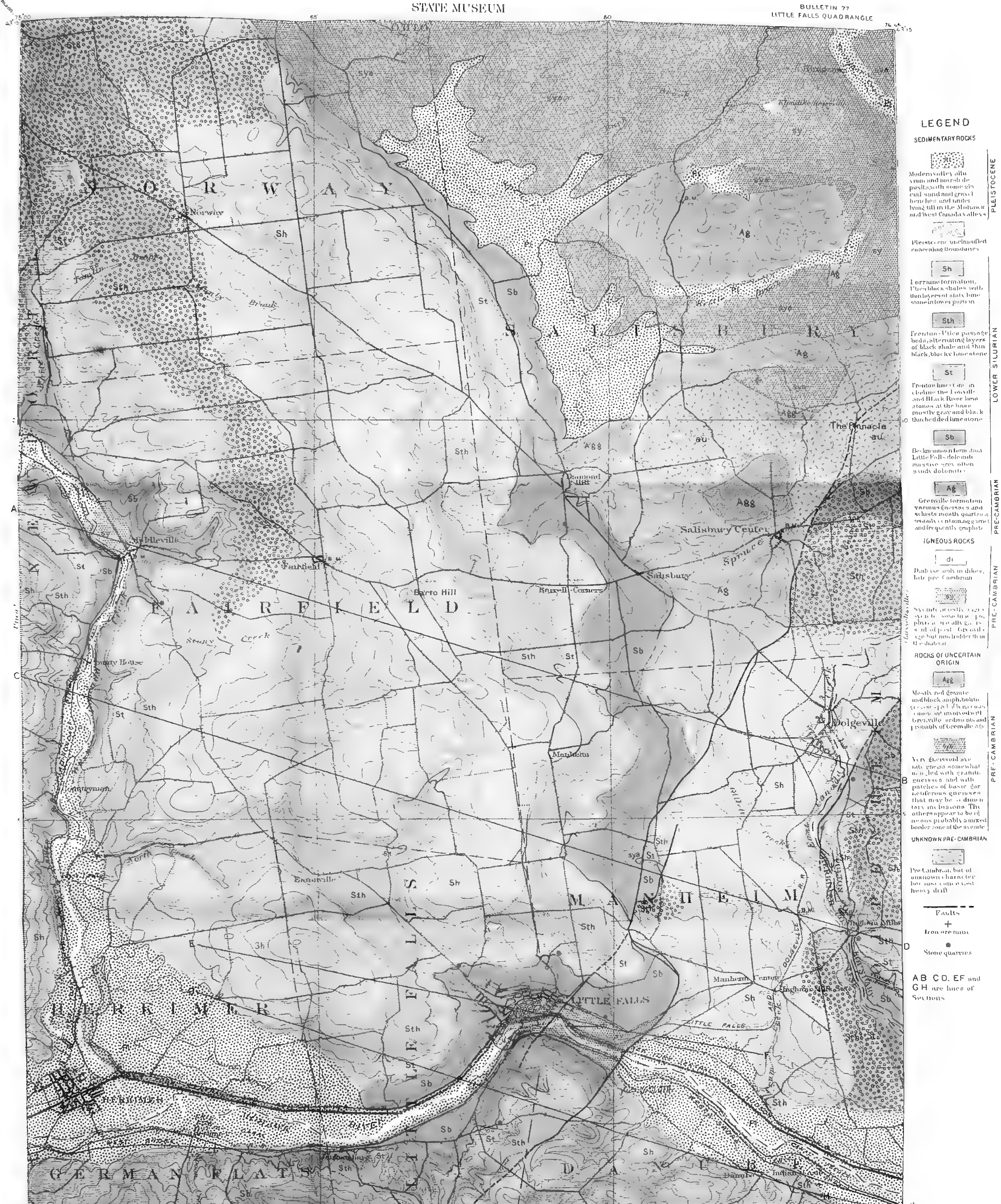
UNIVERSITY OF THE STATE OF NEW YORK
STATE MUSEUM

BULLETIN 77
LITTLE FALLS QUADRANGLE




(Richfield Springs)

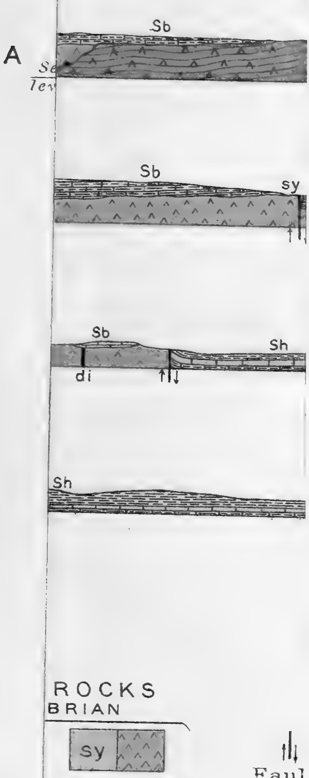
H.M.Wilson, Geographer in charge.
Triangulation by N.Y. State Survey and Hersey Munroe.
Topography by W.H.Lovell, C.C.Bassett and Hersey Munroe.
Surveyed in 1898 in cooperation with the State of New York.

APPROXIMATE MEAN DECLINATION 1902

Scale 1/62500

Contour interval 20 feet.
Datum is mean sea level

Geology by H.P.Cushing
1901



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## New York State Museum

The New York State Museum as at present organized is the outgrowth of the Natural History Survey of the State commenced in 1836. This was established at the expressed wish of the people to have some definite and positive knowledge of the mineral resources and of the vegetable and animal forms of the State. This wish was stated in memorials presented to the Legislature in 1834 by the Albany Institute and in 1835 by the American Institute of New York city and as a result of these and other influences the Legislature of 1835 passed a resolution requesting the secretary of state to report to that body a plan for "a complete geological survey of the State, which shall furnish a scientific and perfect account of its rocks, soils and materials and of their localities; a list of its mineralogical, botanical and zoological productions and provide for procuring and preserving specimens of the same; etc."

Pursuant to this request, Hon. John A. Dix, then secretary of state, presented to the Legislature of 1836 a report proposing a plan for a complete geologic, botanic and zoologic survey of the State. This report was adopted by the Legislature then in session and the governor was authorized to employ competent persons to carry out the plan which was at once put into effect.

The scientific staff of the Natural History Survey of 1836 consisted of John Torrey, botanist; James E. DeKay, zoologist; Lewis C. Beck, mineralogist; W. W. Mather, Ebenezer Emmons, Lardner Vanuxem and Timothy A. Conrad, geologists. In 1837 Professor Conrad was made paleontologist and James Hall, who had been an assistant to Professor Emmons, was appointed geologist to succeed Professor Vanuxem, who took Professor Conrad's place.

The heads of the several departments reported annually to the governor the results of their investigations, and these constituted the annual octavo reports which were published from 1837 to 1841. The final reports were published in quarto form, beginning at the close of the field work in 1841, and 3000 sets have been distributed, comprising four volumes of geology, one of mineralogy, two of botany, five of zoology, five of agriculture, and eight of paleontology.