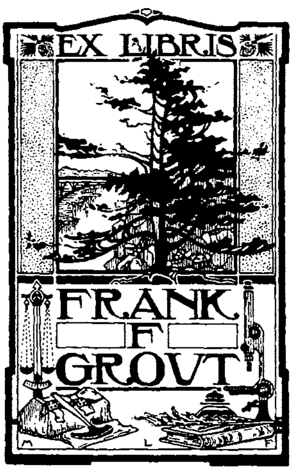
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THE GEOLOGICAL

AND

NATURAL HISTORY SURVEY

OF MINNESOTA.

The Eighteenth Annual Report, for the year 1889.

N. H. WINCHELL,
State Geologist.

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ADDRESS.

THE UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, March 3, 1890.

To the President of the University.

DEAR SIR: With the round of another year I herewith report the progress made in the geological and natural history survey of the state. During the year there has been considerable interruption incident to the removal and installment of the museum and survey headquarters in the new Science Hall. This was aggravated by the fire which unfortunately broke out in the building in the latter part of December, and which, while not consuming much, yet so damaged the rooms and their contents that it necessitated the renovation of the entire building, and the cleaning of most of the specimens and apparatus. This report gives an idea of the progress that is being made in the intricate geology of the north-eastern part of the state, and of the economic resources that are being developed there. That part which discusses the iron ores of the state is planned to be published as a separate bulletin of the survey.—Bulletin No. 6. It is accompanied by numerous illustrations and a geological map.

Respectfully, your obedient servant,
N. H. WINCHELL,
State Geologist and Curator of the General Museum.

REPORT.

I.

SUMMARY STATEMENT FOR 1889.

There was not much field-work done in 1889. This was due to the change from field-work to office and laboratory work which was announced in the last annual report incident on the commencement of the final report on the northern part of the state. In July, however, a special reconnoissance was made of the iron-deposits and the mines at Tower and Ely, in order to get some details of the relations of the ore-bodies to the country rock as developed about the works, and of the methods of mining and transportation. In some directions this review was extended into the surrounding country whenever there was promise of new facts either economic or scientific. This re-examination resulted in the acquirement of of many interesting facts of detail, and in the establishment or the rejection of some hypotheses as to the origin of the ore bodies, and the genetic history of the rocks embracing them. It was thought that with the light of the field observations made during the previous three years fresh in mind, and with all the known theories of the ore and of the general geology that had been proposed whether by the Minnesota survey or by others, immediately and continually under test and application, such a careful investigation would be a valuable preparation for the discussion of the crystalline rocks which was contemplated, and especially for the exposition of the iron ores contained in Bulletin No. 6. This review was made in conjunction with Mr. H. V. Winchell; and inasmuch as the progress of the investigation here, as elsewhere, has been frequently the result of our joint work and mutual co-operative study, the bulletin devoted to the iron ores herewith transmitted bears our joint authorship.

Within the past year two other bulletins have been published, viz., *Natural Gas in Minnesota,* and *The History of Geological Surveys in Minnesota.*

The Legislature of 1889 failed to make provision for the publication of the two final volumes of the survey report referred to in the last annual statement. This failure, however, was not due so much to indifference on the part of the Legislature as a whole, as to the unfriendly manipulation of some of the committees, and the neglect of the public officials having in charge the estimates and recommendations for the current expenses. The reports of the survey were eagerly sought by all the legislators, both for themselves and for their friends. They were aggrieved when they found that by law this distribution was not wholly gratuitous and instant, and they desired the publication of the final volumes as fast as they can be got ready. The bill for a law, however, making provision by a money appropriation for the printing of the manuscripts now on hand was delayed by the chairman of the committee having it in charge until it was too late to get the appropriation allowed by the general finance committee and acted on by both houses of the Legislature. The same will be offered for publication at the next session of the Legislature (1891).

In the summer of 1889 the museum and all the paraphernalia of the survey were removed from the "main building" of the University, where it has been located since 1872, to the new Science Hall. The building was not yet completed, but the removal had to be made to give opportunity to fit the old rooms for other use prior to the opening of the fall term of the University. The building was nearly finished, and some work had been given to the museum and to the equipment of the various rooms, and plans had been entered upon for office and laboratory work, when another interruption was suffered (Dec. —) by the (supposed) spontaneous starting of a fire in the engine room, where painters had been at work with naphtha and white lead. This kept the survey work largely in abeyance till about Feb. 15, 1890, when the building had been again sufficiently restored, and the damaged rooms renovated, to permit of their regular occupancy. Thus it will be seen that the work of more than six months has been so broken and unsatisfactory that it will not permit a very cheerful view to be taken of the aggregate progress of the year. Still, unless some other unfavorable cause interfere, the commodious rooms now occupied by the survey for office, drafting room, laboratories, museum and storage, will, when fully equipped with apparatus, and the library with reference books, warrant the expectation that the nicer researches that remain to be done in order to "finish" the survey of the state, will go forward with ease and dispatch.

The Museum now needs replenishing. The room that is given to it is more than four times as large as that which it occupied in the other building, and numerous new cases ought to be constructed.

This is true particularly of the zoological collections, which have been put in the special charge of professor Nachtrieb. In the geological museum, while the old cases have been refitted and made to answer for the present, there is a need of mineralogical specimens and there will be soon need of other cases for exhibition. Some of the specimens of the Kunz collection purchased in 1376 have been lost. Many of them are permanently removed from exhibition in the museum and stored in the geological lecture room. Indeed many of the unique and attractive specimens formerly kept in the museum for exhibition have been missing from their places from that cause for some years, and some have been badly damaged. The mineral collection has thus inevitably deteriorated, and ought to be replenished by occasional purchase. Of course donations aid in keeping the collections (i. e. the cases) apparently full, but donations do not supply first-class material.

State Park. I wish to call the attention of the regents, and through their report, the attention of the public and the Legislature to the propriety of asking a reservation of land for a state park in some section in the northern part of the state. The geographic positon of Minnesota is on that border land which exhibits the transition of the forested area into the prairie. It hence preserves the faunal and floral characteristic of both, and within its territory must be studied by naturalists the mutual modifications and interchanges which the near neighborhood and contact of different physical features always imprint on the native vegetation and animal life found therein. By settlement and long babitation the natural conditions are destroyed and the natural laws that could perhaps be discovered by an examination of them in their original state, are never known. Hence as long as the natural conditions exist the state of Minnesota will be visited by students and collectors interested in natural science for the purpose of investigation, and this will bring Minnesota into prominent recognition in scientific literature and secondarily into scientific and economic research. It hence behooves the State to preserve, to such extent as may be found desirable and feasible, these natural and aboriginal conditions, and for this purpose there is no better method than to reserve from sale and settlement some considerable tract where they may not be destroyed.

Again the state should have a large public park because of the healthful resort that it ould afford for those living in cities, and for those who, coming from further south, seek in summer the invigorating effect of northern latitudes. The attractions of a multitude of lakes, rivers and rivulets of limpid and pure water, are confined in the United States, to the northern tier, where the tumuli of the glacial epoch formed the depressions and natural reservoirs of gravel and sand, such as mark its moraines from Maine to Minnesota. In Dakota these lines of tumuli pass across the prairies northwestward to the line of British America and do not return again sensibly within the United states, Hence it is within Minnesota that exists the last opportunity to preserve the pristine conditions of that unique combination of physical and faunal relations which alike distinguishes them from all other natural surface conditions in the United States, and has attracted to them always the venturesome, wandering explorer, the artist, the geologist, and the hardy frontier settler.

This park should be located either in the region northeast of lake Superior, enclosing some of the rock-bordered and rock-bottomed lakes that are a natural curiosity to every traveler, or in the area about the head waters of the Mississippi. General J. H. Baker, when surveyor-general of Minnesota, some years ago, urged that such a park be established on the international boundary line north of lake Superior, and specified the region of lake Saganaga. Since then, the region of the Itascan source of the Mississippi river has come into prominence, and it has served as the topic of several explorations and new "journals," which have given it already a renown equal to the earlier historic interests that cling to it since the days of Lieut. Allen, of H. R. Schoolcraft and Jean Nicollet. These artificial elements enter strongly into the question of making the selection for a state park, and bear heavily in favor of the sources of the Mississippi for such a selection. There is, fortunately, a perfect exemplification of the natural surface features that characterize the glacial moraines of the state within a few miles of the Itasca lake, and, indeed, they give outline and location to the entire Itascan basin, and would thus serve to embrace, within easy access or in combination, both the natural and the artificial considerations. This region is, moreover, remote from lake Superior, and its attractions, by contrast with the surrounding country, would be hightened in the mind of every visitor. Whereas, in the northeastern part of the state, lake Superior and its attendant waters and surrounding hills, dominate the district, so that no selection could be made whose attractions would rise above those of the great lake itself.

It is presumed that there would be no difficulty, whether in the northeastern or the northwestern part of the state, or even in both, in getting the consent and cooperation of the United States government by the withdrawal of the lands concerned from the market, and perhaps of any private parties who may have received some of the lands from the United States, or from the State of Minnesota. At any rate, no time should be lost in entering upon the project, because of changes and increased difficulties that will render it impossible not many years hence.

The laboratory and office of the survey ought to be supplied with apparatus and books needed for the work that lies immediately before it. This is a matter of absolute necessity. It were better that all other expenses cease entirely till there be sufficient funds for this necessity, or that a special appropriation be made by the Legislature to provide them.

II.

Record of Field-Observations in 1888.

On the Mesabi Iron Range. Mallmann's mining camp is on the Duluth and Iron Range railroad, about two miles south of Hinsdale on the Giant's range of granite hills. The working is for iron ore. There are a number of pits or shafts sunk to the rock, from 15 to 50 feet in depth, and they have uniformly encountered the same magneto-bedded rock that Chester did on the Mesabi range a few miles further northeast* and of a character identical with that seen near the west end of Gunflint lake,** both being a part of the Animike, and probably in the lower portion of it. About half a mile further south is a cut by the railroad in real Animike slate. Some of the ore he finds is hematite, and he hopes to get enough that is hematite to warrant his enterprise. This working is just west from the "red cut" which is mentioned in the 13th report in giving a description of a trip to Tower, and in one of the shafts he has struck this red hematite mass. The rock seems to be more rotted in this red mass.

This magneto-bedded rock is nondescript. It has been referred to sometimes as quartzyte, but it generally contains not enough free quartz to entitle it to that designation. It is gray, medium-grained, sometimes fine-grained, has a mineral, apparently a feldspar, that changes by rot to a white kaolinic substance, or to a rusty powder, and is the rock in which is scattered the magnetite ore both here and at Gunflint lake, as well as at Chub (Akeley) lake. This ore is in lenticular bunches, elongated in the direction of the general bedding, and is generally not pure magnetite, but is seen to increase and fade again in the midst of the rock, sometimes

* See Eleventh Annual Report, p. 156
** See Sixteenth Report, pp. 80, 267.

extending in parallel bands from half an inch to an inch wide, and a foot or more in length. It is this same rock which accompanies the hematite, which inspires Mallmann with fresh hope. Apparently the hematite is disseminated in it in the same way as the magnetite. Mallmann is confident the ore here is the same as the ore mined at Tower, and in the same kind of rock—a mistake which we tried to correct. There is no question but the vertical greenish schists and graywackes seen at*the Tower mines are repeated south of the Giant's range, and pass uncomformably below the Animike along the line of strike all the way from Gunflint lake to this point, and that they may be encountered after passing through the slates and quartzytes of the Animike. It is likely also that they are as apt to carry iron-ore lenses on the south side of that range as on the north side. But owing to the prevalence of the drift, and the concealment of these schists by the overlapping of the Animike, it would be a herculean and problematical task to seek to find such ore bodies by shafting through the Animike. It would not be impossible that a shaft should go down through the Animike, and should encounter one of these ore bodies in the Keewatin, but the chances against such an event would be many thousands to one. It is probable therefore that all the ore found by Mallmann here is from the Animike beds.

Observations about Tower. We visited again the vertical black slaty crag north of Tower, in the southern slope of the south ridge (photographed in 1886), and noted the abrupt and uncomformable transition from the slate to the green schist. This occurs a little west from the crag, and in a lower place. There is no indication that either underlies or overlies, as the line of contact is on a nearly horizontal plane surface. The structure and bedding of the slate is interrupted somewhat obliquely by that of the schist, and shows plainly some kind of unconformity. This slate is siliceous and has all the banding of the jaspilyte, but is not colored. A little further north it is like jaspilyte. Indeed, it passes into the rock which is, or which becomes, or which embraces the ore.

Thence we went further west and after considerable search we found the low, bare, slaty knoll, consisting of fissile slate, which was mentioned in the report of **1886, in which was recorded a gradual passage from the clay slate to the chlorite slate of the region. We examined it to find sedimentary banding. While this banding is not, in the knoll, characteristically exhibited, yet there

*Compare H. V. Winchell's report on this region, 17th report, pp. 88-9.
**Fifteenth report, p 267.

are some long, parallel, color-bands, about one-sixteenth to one-half inch wide, that appear to be due to sedimentary action. It is noteworthy that throughout this knoll of clay slate, generally no such bands are visible. This may be due to the shattered condition of the rock and the obliteration of an original structure by the process of acquiring the slatiness. Toward the east, the slate, followed along the strike, *evidently gets more and more siliceous*, till, after some intervals of non-observation due to drift and to brush, it is converted into jaspilyte, first passing through the condition of the slate crag described above. But there is in the midst of this slate, further east, a little greenish, coarse sericitic and quartzose slaty-rock (No. 1505), apparently alternating with the clayey slate, which may be the parallel of the schist seen to alternate with the jaspilyte rock, as at the railroad cut south of the Stone mine. This indicates that, as formerly supposed, there is a close alliance between the clay slate and the green schist, or at least *a schist* which cannot with any certainty *or satisfaction be distinguished from it*, and again an alliance that implies some community of origin and structure between all three of these schists. In following the strike along toward the east from this knoll we saw a bed about fourteen inches thick of such green schist (but rather darker and coarser grained), *imbedded in the jaspilyte**. The lack of sedimentary signs (*i. e.*, the general lack) caused me to query whether the eruptive green schists could become changed to argillyte, but on finding some, not very distinct, trace of bedding, and especially on seeing the argillyte bed change, in the direction of its strike, apparently first to siliceous slate and then to jaspilitic beds, the conclusion is found inevitable that the argillyte at least is an originally sedimentary rock.

But this leaves to still be accounted for the green (or gray when siliceous) schist which usually resembles closely the green schist which is supposed to be of originally eruptive origin, seen interbedded with the argillyte. On the suppositions that it is of identical genetic origin with the eruptive green schist, it may be supposed to have been brought there by slight eruptions at the time of the sedimentation of the argillyte, and that would rather require that all the supposed eruptive green schist which embraces the jaspilyte, originated in the same way, *i. e*, in a manner similar to the eruptive sheets of the Cupriferous, and is now interbedded in the great (Keewatin) formation, as schists, in the same manner. This would make the eruptive green schists date from the time of

*Compare Bulletin No. 6, where such a layer of silicious green schist is described on the north slope of the "north ridge," embraced in the contorted jaspilyte.

the Keewatin itself, and the green schists would be found to be, on a large scale, conformable with the adjacent rock, instead of being of the nature of later overflows and uncomformable with it. The latter supposition was expressed in the 15th annual report.* I do not know that there is any necessary and known objection to that hypothesis. It would be necessary still to account for the rock having now the condition and structure of a schist and for its being sometimes the matrix for a multitude of fine pebbles of jaspilyte.

But it is not by any means certain yet that this gray schist (1505) is identical with, or can be found to grade into, the great body of green schist of the region, so that they can be embraced in the same general hypothesis.

We went over the south ridge at the Lee mine and west from there, and the following facts were noted:

1. In some places the jaspilyte is wonderfully brecciated over large areas, the same parts again cemented by the ferruginated granular silica, or by the same in a finer breccia, so that the general mass is as hard as the jaspilyte unbroken, and in this condition shows large glaciated areas.

2. When broken less minutely the cement is, in some other places, pure hematite, and when this has accumulated in large enough masses, filling pre-existing cavities whose forms it takes on, it is valuable as ore, and as such is the principal basis of the working of the Lee mine.

3. This accumulation of hematite, or re-cementation, took place before the deposition of any vitreous silica, or before any observable "silicification."

4. Chemical (*i. e.*, vitreous) silica was afterward deposited in openings and geodes in this hematite, and in veins crossing both the hematite and the jaspilyte, this being the last observable step.

5. I do not see hematite veins crossing chemical silica veins.

6. Hematite veins cross jaspilyte in all its forms, whether in breccia or as undisturbed strata in the jaspilyte.

7. Chemical silica veins and nodules occur latest and cross the hematite and also the jaspilyte.

This seems to show that there were two processes after the deposition of the original sediments forming the jaspilyte, viz., a ferruginization and a silicification, and that the former preceded. But, as already argued in the fifteenth report, the chalcedonic silica was not concerned in either of them, except that the rounded

*Page 221, 269, 322.

grains have become angular by deposition of interstitial silica. Samples 1506 show the relations of the chemical silica to the hematite, and 1507 show the brecciated jaspilyte cemented by a finer breccia of the same.

On Chester Peak (or Jasper Peak, so generally called at Tower), on the northwest side and shoulder, the jaspilyte dips north at an angle of about eighty degrees. It suddenly changes and dips west at seventy-five degrees, then as suddenly changes and dips east at seventy-five degrees. It then veers round on the apex of the hill so as to dip northeast at seventy degrees. In the easterly part, which is lower, the dip is north again. The hill is abrupt and short, but elongated about east and west. A stretch of drift, like a morainic ridge, rising about fifty feet, connects the hill with the "north ridge," in which are the mines of the Minnesota Iron Company; but there seems to be no rock-ridge uniting them. The "north ridge" dies out toward the east, although a series of low hills, making a lower range, can be seen to run along the south side of Vermilion lake and eastward. Toward the south the range of the Giant's hills can be seen from where it rises, on the south side of Birch lake to where they run out in the distance toward the west. They have openings and sudden elevations, but are without any notable peaks, the highest and apparently the most important hills being toward the southwest rather than south.

Numerous pits have been sunk by the iron company to the rock in the vicinity of this peak, and between it and the "north ridge". Some of them strike green schist, some a jaspilyte without ore, or a lean ore, and some of them reveal good ore. But in one of them, at the northwestern base of the peak, a black schist, soft and (carbonaceous?) holding balls of pyrite (1508) from a bullet's size to two and a half inches in diameter, was met in the bottom of the shaft. On the northern face of this hill are the green schists, seen at the mines, mixed and twisted with the jaspilyte. A deep drill hole on the south side of this hill afforded the diamond drill a core of porphyrel at several hundred feet below the surface, the hole sloping north.

Glaciated surfaces are seen nearly to the top, and a few boulders lie on the very top.

Some small veins in the brown jaspilyte consist of white chalcedonic silica (1509) crossing the jaspilyte banding. In the immediate vicinity are deposits of chemical silica. The existence of chalcedonic veins is a very rare occurrence, and has been observed, though doubtfully, but once before. Compare the fifteenth report, p. 324, and rock sample 1013. There must be some way to account for these chalcedonic veins. They do not appear to have been formed by mechanical transposition of laminæ in or across the jaspilyte strata. They do not have any banding or crystallization like true veins. They form a network connecting a coarse (and in some places a fine) breccia of brown fine-laminated jasper. These are on the exposed upper surface of the glaciated apex of the knob. The silica is white, and appears to have the effect and disposition of vein matter but not its structure. This hill is in nw ¼ ne ¼ sec. 35, 62–15.

At Ely. The rock-cuts all the way from Tower to Ely, so far as seen from the train, are all in the green schist, or a green rock more massive than schist which imperceptibly takes its place, and at Ely is the rock which has there been described in the field-observations of 1886 (Fifteenth Report, pp. 325–26), and which extends from Ely to the shore of Shagawa (Long) lake, and really which goes also to Fall lake and there forms the falls. At the rail road cut at Ely it exhibits some new features, viz:

1. It is made up of rounded masses of itself, or rock like itself, some of them four feet across, and some not more than three inches.

2. The rock matter between the rounded masses is darker green than the rounded boulders, and squeezes among them in the same manner as green schists between jaspilyte boulders at Tower. It is also more apt to be a little schistose.

3. There is no bedding like sedimentation, but an angular coarse jointage like that of eruptive rock which has flowed in a broad sheet over the surface. The forms of these boulders are visible in the weathered surface, and their slickensided (and then darker) exteriors are shown on the face of the railroad cut.

4. The boulders are frequently amygdaloidal, calcite being the mineral enclosed; but the cavities are rendered conspicuous by the easy weathering out of the calcite.

5. There is a crust of somewhat darker rock that surrounds the interior of the boulders, and these cavities are most abundant in it; they are commonly in the form of tubes that cross this crust approximately at right angles, radiating as from the centre, though not reaching the centre. Transverse to these tubes this crust sometimes exhibits a dim linear structure that appears to be fluidal.

6. This green rock contains chalcedonic silica, disseminated all through it, and it seems to result from a change in the chemical silica

7. This green rock is of the same genetic nature, and the same in all its physical aspects, with the exception of such as can be referred to difference of weathering, as the Stuntz Island conglomer-

ate, but the enclosed boulders are less siliceous than the most of those in that conglomerate.

8. The rock that embraces these boulders is not usually, but is rarely, amygdaloidal. This is the rock which I designated, in this vicinity last year (1887), and before*, as modified graywcake, but it seems now never to have been in the form of graywacke.

No. 1510 is a sample of this green rock, showing the forms of two boulders, and the darker-green rock separating them.

No. 1511 contains amygdaloidal portions of some of the boulders, showing the tubes perpendicular to the surface, one specimen having a glaciated surface. (Compare Plate 1, Sixteenth Annual report).

No. 1512 has chalcedonic silica from veins and spots in the rock 1510.

No. 1513. Vein matter in No. 1510, similar to 1501 which is from the so-called gold-quartz vein at Eagle Nest lake.

In returning from Ely to Tower the conglomeratic (or agglomeratic) character of the green stone was more frequently noticed at the occasional cuts. The rock is angularly and cuboidally jointed in most of the cuts, with a light green color, weathers lighter, but in some cuts it is a schist with a slaty tendency in disintegration, and has doubtless been called sericitic schist in many places.

Southward from Tower this rock continues, as seen from the train, as far as nearly to the gneiss exposures that appertain to the northern flank of the Giant's range. It has been reported by H. V. Winchell** that there is no exposure of mica schist between its last exposure and the first of the gneiss. There is an unobserved interval, however, between the two amounting to about two miles in which there may still be a narrow belt of mica schist.

[NOTE. In the spring of 1890 a belt of mica-hornblende schist was exposed in some railroad cuts, a few miles north of the Giant's range syenite.]

Pokegama Falls and eastward to Griffin's camp. At the falls of Pokegama the dip of the quartzyte was carefully measured at several points, with the following results: Below the falls, S. 8° W. about 15 degrees; above the falls, S. 8° E. about 15 degrees; at the bluff, on the west side of the river, a sixth of a mile above the falls, S. 22° E. 8 degrees.

The rock is quartzyte, red superficially (from six to twelve inches) and gray within. The bluff above mentioned is 27 feet

*Fifteenth report, p. 326.

**Seventeenth report, p. 89.

high above the water, and the beds composing it seem to strike southeastward to the falls. Mr. Griffin says this rock runs under the river which is the outlet to Pokegama lake, and used to cause rapids at half a mile below the lake, in Sec. 23, T. 55-26. But now these rapids are covered by the setting back of the water into the lake from the Mississippi from the government dam, which is built just above the falls. He also says he thinks he saw once (as surveyor) an outcrop of it on Little Boy river, about in the line of strike from Pokegama falls. H. V. Winchell also reports having seen it on Little Boy river. Mr. Griffin also is authority for an outcrop of the same rock about eight miles southwest from Pokegama falls. In 1871 or 1872, as deputy surveyor, he also noted the same rock north from Sugar lake (two or three miles) in Sec. 6 or 31. This rock appears to be the Pewabic quartzyte, so named much further northeast on the southerly slopes of the Giant's range.

October 18, 1888. In the rain (there was a drizzling rain all the rest of the day) we went to the falls of Prairie river, first seeing the granite at the upper falls.

There is a large display here of gray gneiss, some of it being micaceous, and some of it having hornblendic, dark masses and belts cutting through it. In some rare places it is laminated in thin indistinct laminæ of mica and feldspathic sheets. Its dark belts and isolated masses recall the rock at Morton, on the Minnesota river (see another section of this year's report) and north of Vermilion lake, but there being so little of this it will not be correct to parallelize it with the mica-hornblende series. It is rather the extension of the Giant's range rocks, which are mostly without noticeable micaceous or dark hornblende laminations, and generally a more massive rock than the micaceous gneisses of the Vermilion series. At one point on the west bank of the river there is a rude horizontal, undulating stratification or bedding. On the east bank opposite this, however, the gneiss is conspicuously basaltically jointed It is probable, therefore, that the former may be due to weathering upon a spot where by a shearing pressure a local lamination had been superinduced. There are also in some places in the gneiss, thin alternations with a shining micaceous schist running about horizontal, such that the general aspect and average composition is quite different from the rock in general (see No. 1523). Red orthoclastic belts (1524) more coarsely crystalline, containing also coarse quartz crystals, run irregularly through the mass. In one spot a wedge of reddish rock, associated with chlorite, making a (protogine?) runs through it.

We do not see the contract of this gneiss with the overlying quartzyte. The latter is seen at the lower falls and while dipping in the main to the s. s. e. about 10 degrees (sometimes 12 degrees) it undulates in one or two synclinals. Along the top of one of the anticlinals can be seen a distinct fracture, opening somewhat upward, as the crest runs across the river.

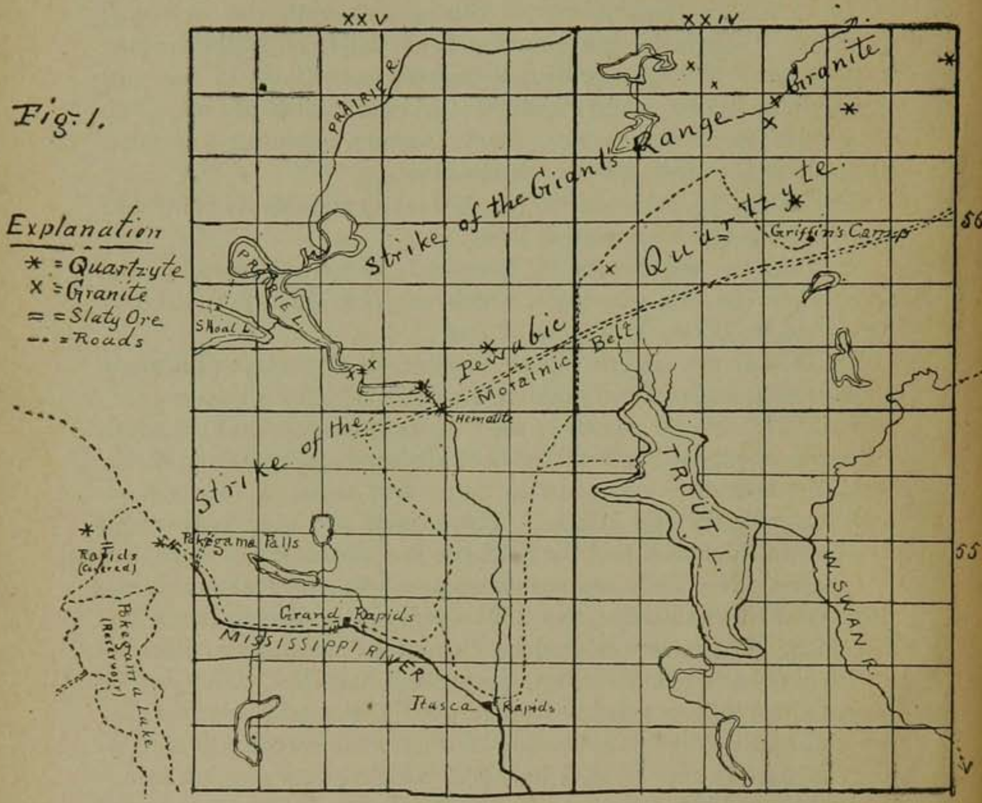
Glacial marks here run S 10° E. (mag.) and Mr. Griffin says there is no magnetic variation here.

No. 1525 (a) represents an incipient or pseudo-amygdaloidal spottedness in this quartzyte, which may be allied to that lately described by Bailey at Pigeon Point.

No. 1526 shows another spottedness in this quartzyte, the rusty spots weathering out and making the surface pitted all over.

No. 1527. So far as can be seen then comes on toward the south (after an unexposed interval) a lot of siliceous and hematitic cherty beds, the hematite in some cases being fine, massive, nearly pure, and finely basaltically jointed. These beds are seen only about five feet in thickness, and the hematite is apparently not more than six inches. No. 1528 represents some of the rock about at the horizon of this hematite. No. 1529 somewhat above (in the beds). No. 1528. This shows a curious "streamed" mixture, and brecciated bed of chalcedonic silica, jasper and hematite, with vitreous glassy silica filling veins or former geodic elongated cavities that are embraced entirely in a casing of white chalcedonic silica. The highest part is represented by 1530, which has a very different aspect from 1529, being a coarser, evidently fragmental, rusty, siliceous, somewhat vesicular rock, but yet may be only a modified condition of 1529. It has pure hematitic sheets and lumps, and is, in general, bedded, and dips conformably with the quartzyte below, in beds fron six to ten inches thick. It is mainly a felsyte with hematite, some of the beds having the bloodstone distribution seen in some at the east end of Gunflint lake. Some of the quartzyte that underlies is conglomeritic (1532) in patches, but it is not seen so in any continued layers.

In making the trip from Grand Rapids to Griffin's camp (see sketch-map, fig. 1, p 16),we traveled eighteen miles over an execrable road in an autumn snow storm which not only kept our clothing wet but loaded every bush with dripping snow and water. As we had been in the rain the greater part of the previous day, and returned the following day in a snow storm of the same kind but somewhat cooler air, we found the three days productive of results not entirely geologic.



The trip was very useful in a geological sense, but it cannot be said to have afforded sufficient evidence to answer the question of the true relation of the Pewabic quartzyte to the black slate of the Animikie. So far as the evidence goes, *unless there be two great quartzytes*, it seems to indicate that the Pewabic quartzyte overlies the black slate, although it is next in contact with or adjoining the granite all along the south side of the Giant's range and as far west as to Pokegama falls, at the latter place the quartzyte being separated from the gneiss by an unexposed interval of unknown strata, which is presumed to be occupied by the Animike slates proper. This evidence consists in the existence of the red soft shale (1533) above the quartzyte (1534), This shale is apparently the equivalent of the red shale which have been penetrated in some deep wells in the central part of the state and found to overlie the quartzyte (the New Ulm quartzyte), and also perhaps of the red shale seen at Black River Falls, Wisconsin, on the south side of the "Tilden mound," to which it bears a strong resemblance, making thus the ore at Black River Falls the equivalent of that in the Animike (Huronian proper) in Minnesota, to which in its lithology and general character it has a close resemblance, as well as in its near proximity to a corresponding range of gneissic hills. It also confirms the opinion, elsewhere expressed by the writer, that the Gogebic ore is probably in the beds which, on the south shore, represent the Animike of the north shore, instead of the beds that contain the ore deposits at Vermilion lake. The structure here is represented by figure 2, showing an ideal section running north and south at Griffin's camp. The horizon is therefore very near that of the works of Mallmann, and of the mines in the Gogebic region.

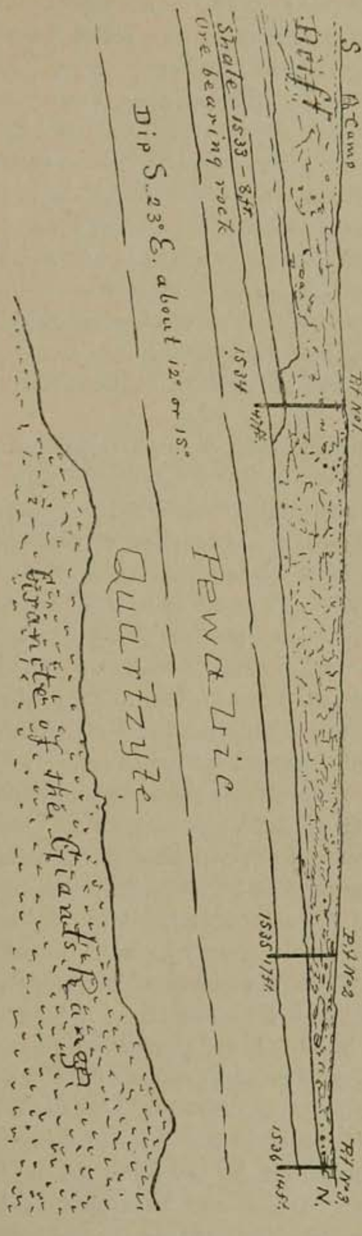


Fig. 2.

There is yet one troublesome unexplained fact, which does not fall into place in accord with the idea that there is but one quartzyte and that it overlies the black slate unconformably, viz: The ore mines on the Gogebic range seem all to have an important granular gray quartzyte underlying them, and, according to all I know, a black slate lying to the north of them and probably stratigraphically above the ore beds, these black slates being supposed to be the Animike. If that quartzyte be the equivalent of the Pewabic quartzyte it certainly runs below the iron horizon, and the Animikie iron, the supposed equivalent of the Gogebic iron strata, should be sought for toward the south from the strike of the Pewabic quartzyte in Minnesota. As there are outcrops of slates and quartzytes, of the Animike series, along south from the strike of the Pewabic quartzyte it is also legitimate to infer in the absence of facts demonstrating to the contrary, that in Minnesota also the main mass of the Animikie, and hence also the horizon of the Gogebic ore, lies conformably above the Pewabic quartzyte, and may be found to the south of the strike of the quartzyte. In all the reports and inferences that have been published by the writer the Pewabic quartzyte has been made the parallel of the great quartzyte that overlies the Animikie unconformably, but it is possible that it runs below it conformably. Its age in either case is that of the great gabbro flood, with which it is interbedded at points further northeast.

Specimens from Griffin's camp, ne¼, sec. 22, 56-24, No. 1533, red shale, 8 feet; No. 1534, iron bearing rock, somewhat siliceous, ore-sheets broken and irregular, hematite; No. 1535, same as 1534, pit No. 2. but reached at 15 feet below the surface; No. 1536, same as 1534, 11 feet below the surface. No. 1537, slaty ore, rather low grade, (47 p. c.) nw¼, nw¼, sec. 21, 56-24. Mr. Griffin says that in sec. 21 he knows that the rock 1537, lies to the south from the rock 1535 and 1536, in outcrop in the same section. He also says that at three or four miles south from his camp fragments of black slate are abundant in the drift, indicating black slate lying above the rock seen at his camp.

Where the road crosses the morainic belt (see the sketch map, Fig. 1,) between towns XXIV and XXV, the hills are very conspicuous. It appears that the morainic belt coincides, in general, with the strike of the quartzyte, a fact which has been noticed before in Minnesota (and in Ohio, in case of a strike of the limestone as in Delaware county), and it is very likely that the existence of the latter had a powerful influence in determining the southward limit of the drift-laden ice.

That this range of iron ore is independent of and quite different from that at Vermilion lake, which is in the Keewatin schists, is shown, not only by the general geology and geography, and the difference in the manner of occurrence, as well as in the ores themselves, but by the fact that the line of strike of the Keewatin ore belt from Tower westward is found to cross the country about thirty miles further north. It has been discovered at several points, where it affords very encouraging outcrops, and samples of first-class magnetite have been exhibited by those who have visited the region. Mr. John Beckfelt, postmester at Grand

Rapids, ** has manifested an intelligent interest in this more northern iron region, and from the samples in his possession the following were obtained: No. 1538, magnetic iron ore, sec. 23, 60, 23; No. 1539, rock associated with 1538. This is magnetic and siliceous, black, fine grained, apparently a magnetic jaspilyte. * This is described as standing vertical in the midst of vertical green schists. Charles Kearney, Grand Rapids, owns an iron location on sec. 27, 60-23, and — Fleck on sec. 23, 60-23; other owners are reported to be Lawrence Welsh, James Gill, Eli Signal, William Wynn, Al. Tory, J. H. Hennessy and — Knutson.

According to Mr. Griffin, there is an outcrop of "granite" at a point about ten miles south of Leech lake, the exact position of which he could not give. This indicates the strike of the Giant's range granite.

Gold in the Keewatin schists in northern Minnesota. It is well known that about twenty years ago, a gold excitement sprung up in Minnesota, centering on Vermilion lake.† Mr. H. H. Eames, the state geologist at that time, was largely instrumental in promoting the popular interest in that region, and in the reputed discovery of gold. The excitement subsided soon, and ever since then there has been very little said on the subject. But it appears now that there was some basis of fact underlying the excitement, and that possibly in the future the interest that subsided in 1866 may be partially revived. Several assays of auriferous quartz were published by Mr. Eames in his reports, some performed by J. R. Eckfelt, assayer of the U. S. mint at Philadelphia, others by professor E. Dent, New York, and by himself, which afforded gold amounting from twenty to thirty dollars per ton of the ore, with three or four dollars per ton of silver. This came from some of the workings about Vermilion lake.

In 1887, the writer visited the Marquette iron region in Michigan, and the Ropes gold mine northwest from Ishpeming.‖ He was at once impressed with the resemblance between the gold-bearing rocks seen all the way between Deer lake, near Ishpeming, and the Ropes mine and the rocks of the Keewatin, in northern Minnesota,‡ and in all subsequent study, involving this question,

** Mr. Beckfelt also showed samples of lignite found "up the Mississippi river," say about Winnibigoshish lake. He also says it is reported to be found all about the shores of lake Winnibigoshish, in form of "float" pieces. He also states that he has seen pieces found " up the Prairie river."

* The occurrence of magnetic ore in the Keewatin, near Ely, as well as at Tower, is described in Bulletin No. 6.

†Compare the report of H. H. Eames on "The metalliferous region bordering on lake Superior," printed in 1866.

‖Sixteenth annual report, pp. 48-49.

‡Seventeenth annual report, pp. 42-43.

he has placed the two localities provisionally in the same stratigraphic position. This parallelism at once recalled the early reports of finding gold at Vermilion lake, and aroused a suspicion that gold would be proved to exist in the quartz leads in the Keewatin, in Minnesota.

In 1878, this region came again under examination by the state survey in a rapid reconnoissance, made by the writer, along the international boundary to Vermilion lake, and thence to the St. Louis river, and the principal "locations" were visited. The small specimens collected from the dump heaps were as large as the means of transportation would permit, and of course feebly illustrate what may have been the contents of the veins that were explored by the various owners in 1866. The samples are numbered 395–400, and 423, 428.*

Prof. A. H. Chester again examined these gold-mining locations, and states in his report that "Specimens were collected from many quartz veins, on some of which mines were formerly located, and all were carefully assayed. No true iron pyrites was found, but all was of that form known as pyrohotine or magnetic pyrites. Among the many samples of pyrites, from all parts of the country, assayed for gold at the laboratory of Hamilton college, not one containing magnetic pyrites has shown any gold, and so-called gold mines have been condemned at once when the character of the pyrites was recognized, subsequent assay always corroborating the opinion. It was, therefore, not a matter of surprise that these 'gold ores' did not contain any gold."‡

In 1886 Dr. A. Winchell examined the town in which is situated a prominent white quartz vein in which it was reported gold and silver had been found, and his collected samples at this point are numbered (of his series) 48-53.** He says: "Many quartz veins run through the whole formation. Rock 52 is a sample, containing hematitic stains, very much, indeed, as in some argentiferous[auriferous?] quartz. Other quartz veins are pervaded by pyrites in abundance, as shown in rock 53. In some cases a mass half the size of one's head is pure pyrites. The pyrites and quartz are sometimes seen to be intersected by minute, sinuous veins of a dark, lustrous iridescent mineral resembling peacock ore of copper. These are the glittering minerals which sustained, not without some reason, the hopes of the adventurers." At that time this spot was owned by a man, since deceased, named John Leienderker, who had sunk a shallow shaft in 1885.

*Ninth annual report, pp. 98-103.
‡ Eleventh annual report, p. 166.
** Fifteenth report, p. 32.

In 1888, in making some observations on the iron working of John Mallmann, about two miles south of the Giant's range, as reported above, the writer met Mr. Leienderker at Mallman's camp, and obtained from him a small piece of the quartz containing pyrites from his "gold mine" on Eagle Nest lake. Sec. 34, T. 62-14.

Some assays have since been made, viz:

Samples of pyritiferous quartz obtained by A. Winchell, from Leienderker's shaft, with the following result, assayed by Frank C. Smith, Ann Arbor, Mich.

A. Winchell's numbers 49 and 51, gave no trace of gold.

A. Winchell's number 53, gave one-twentieth of an ounce of gold per ton of 2,000 pounds, or $1.00 per ton.

Sample of pyritiferous quartz obtained by the writer from Mr. Leienderker; assayed by Prof. J. A. Dodge, Chem. Series, 212. Survey No. 1501. "Using one-half ounce of the ore, by fire assay, I find a trace of gold and no silver. The amount of gold is too small to be weighed from that quantity of ore; I should estimate it at not more than one-fortieth Troy ounce per ton."

All the samples from the various "locations" about Vermilion lake obtained by the writer in 1878, * assayed as one sample by Prof. C. F. Sidener, Chem. Series, 213, gave no gold nor silver.

The vein at Eagle Nest lake is said to be about 12 feet wide and to carry much pyrites throughout its width. The pyrite in the sample obtained from Mr. Leienderker is not magnetic in fine powder. It has a light brassy color and rectangular, apparently cuboidal, crystallization, which seem to indicate true pyrite. That which Prof. Chester examined was magnetic pyrite which is rarely if ever auriferous, and was at once condemned by him. There is a large amount of magnetic pyrite near the base of the Animike formation at the west end of Gunflint lake, associated with the magnetic ore of the Animike, which is of the same range and age as that investigated by Prof. Chester on the Mesabi range, and it is quite likely that the magnetic pyrite examined by him was obtained in that group of rocks. That has a different aspect and color from the pyrite at Eagle Nest lake, being a copper-steel gray, and also is much softer.

It appears from the foregoing considerations, and the facts that are known, that not only is there no *a priori* obstacle to the expectation of gold in the quartz leads of the Keewatin, but that there is some positive basis of fact to show that it exists there in

* Ninth annual report, pp. 98-103.

quantity sufficient, in some †cases, to make a valuable low grade ore that could be profitably mined by the same methods as those employed in the Black Hills, and at the Ropes mine in Michigan.

THE CRYSTALLINE ROCKS OF THE MINNESOTA VALLEY.

In June 1888 some observations were made about Redwood Falls. At Frazer's quarry, in Honner, (N. Redwood P. O.) which is on the south side of the Minnesota, but on the northwest side of the Redwood, in the bottom lands of the Minnesota river, can be seen gneiss, some of which is prevailingly red on weathered exposures, but on quarrying deeply—and some without being quarried—is gray. This rock is a gneiss, through and through, having a "rift" which is strongly marked, and generally evident in difference of colors and in micaceous belts, the alternations being black, quartzose, feldspathic, reddish, &c. There are some places that show up as a massive, gray gneiss, without much banding, but the whole rock is generally quite banded. Across these forms run granulyte veins, and coincident with the gneissic bands are other orthoclastic belts, some of them plainly fading out into the gray gneiss, and some being distinctly separate for many feet. These are either of chemical deposition entirely, (as when filling transverse fissures) or are produced by slow chemical metamorphism from the original sediments. In two instances one of these veins, about $\frac{3}{4}$ in. wide, running transverse to the grain of the gneiss, split in the center of the vein, and one-half of it adhered to one block, and the other to the other block, when forced by the operations of the mine. This splitting ran about six feet, and showed, when cleared off, a surface 16 in. by 6 ft., and at a distance I took it at first for a vein 16 in. wide because viewed from that direction. This vein matter was coarse red granulyte. Other similar veins when viewed on the broken edge showed a distinct *central plane of union* between the growing accumulations on the opposite side

†Capt. Gibbons, in test-pitting for iron in 63-11, is reported to have found a nugget of gold valued at about four dollars, and Mr. J. G. Emery affirms that in the quartz veins in the greenstone on the southern slope of the Twin peaks south of Ogishkemuncie lake he has very frequently obtained gold. It might also here be recorded that according Mr. Emery, who showed me a sample, a finely granular graphite occurs on lot 9, se ¼ sec. 18, 64-6, (east of Frazer lake). He describes it as surrounded and overlain by gabbro. At a mile further west, and a little north, it shows on the surface in a vein ten feet wide; and pieces as large as a half bushel lie about, as if thrown out by the frost. It is also found on the portage trail (a little north of the trail) from the east end of Frazer lake to the lake next toward the southeast. Considerable iron ore is reported by him in the greenstone, in the north parts of secs. 2 and 3, 64-6, *i e*, in the region of the Twin mountains.

of the original fissure, just as in common mineral veins, thus: Fig. 3. Such a plane would be a plane of weakness, along which in quarrying, the rock would be likely to part.

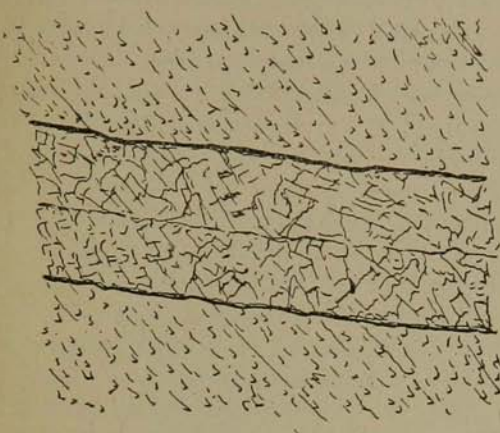


Fig. 3. Layered vein of Granulyte.

At Morton, a few miles below Redwood Falls, situated in the valley of the Minnesota river, Saulspaugh has recently opened extensive quarries in the "granite." Here the rock is mainly a gray contorted gneiss, but it has, in all the usual forms, much reddish feldspar supposed to be othoclase. Veins of granulyte cut the gneissic structure. One was 14 inches wide and was banded in the same manner as illustrated by fig. 3 above, except that its course was nearly perpendicular to the gneissic rift, and it showed, further, a banded alternation of quartz and feldspar, as illustrated by fig. 4 sketched on the spot.

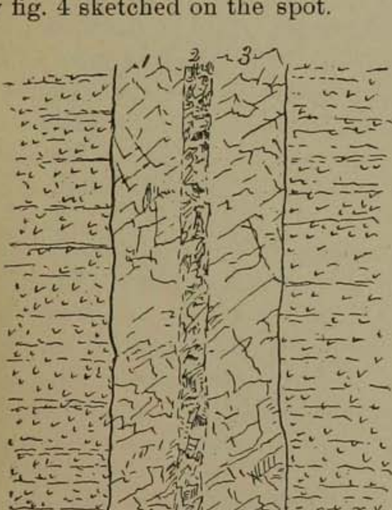


Fig. 4. Vein of Banded Granulyte and Amethystine Quartz.

Explanation of Fig. 4.

No. 1. Coarse orthoclase, with little quartz.

No. 2. Coarse crystals of quartz, somewhat amethystine.

No. 3. Same as No. 1.

This shows a true vein structure, and a chemical origin for the "dyke." The figure shows the planes separating the quartz from the orthoclaserather more abrupt and straight than they are in nature. Along the line of contact some of the orthoclase crystals penetrate within the quartz zone, and there are a few quartz crystals disseminated through the orthoclase. But, as a whole, the central band of amethystine quartz is distinct and constant.

Another remarkable feature in the Morton quarries, where there has been more work done than in any other granite quarries in the state, and from which they have sent rock for street curbing to Duluth, is the beautiful contortion of the gneissic structure, which on being broken, and especially when cut-hammered, makes a striping resembling that seen on some fancy marbles.

And yet another feature, which allies this belt with the transition series at the northwest end of Vermilion lake, is the irregular mixing of the "mica schist," or "black rock," with the gneissic lighter-colored rock. These so-called mica schists appear as isolated masses, one as large as ten feet across, but usually only a few inches in diameter, like boulders in the midst of the gneiss. In one conspicuous instance, seen on a freshly cut block of gneiss, the laminations of the gneiss were seen to shape themselves about the black mass. In many other instances the black patches are changed in shape, apparently by some shearing pressure incident to the whole formation. They are elongated and bent and strung out like hooks and lenticular bands, in conformity with the direction of the general trends of the gneissic contortions.

While these black patches appear (now) to be largely micaceous and of the same nature as the micaceous element in the gneiss, yet there is noticeable a difference. They seem to be of changed hornblende or hornblendic rock (1519.) The "black rock" in one limited space was seen to comprise at least half of the whole, and it seemed to be the same ingredient as the black element in the gneiss—at least so far as its distribution and relations could be seen to show anything of its origin. This "black rock" should not be confounded with another "black rock" which in the form of a conspicuous more recent dyke cuts across the hill composed of gneiss.

The general similarity of this quarry to the mixed condition of the mica schist and syenite in the northwest part of Vermilion lake, where the Vermilion series fades out into the gneiss proper, of the Laurentian, is forcibly impressed on the mind of any one who is familiar with the latter. The transition in the Minnesota valley, however, seems to occupy a wide belt, as it extends at least from Redwood to Morton—and indeed to occupy nearly the whole valley.

In town 111-38 (unorganized), of Redwood county, sec. 12, is a glaciated granite knob, the striæ running S. about 45° E. This is a dome of gray contorted gneiss, rising about twelve feet. Its visible extent is about 200 feet, and 90 feet across. Its elongation is NW. and SE. It is a good rock for heavy quarrying, as it is not much jointed. It is heavily bedded by a series of overlying layers that dip gently toward the south, so that the steep side of the knob is on the north slope. The country round about it is wild, unoccupied prairie, smoothly rolling.

This rock shows no red feldspar, in that respect being somewhat more like the Honner quarry than the gneiss at Morton. The top is somewhat below the average level of the country, and has been uncovered by the removal, by some means, of the drift cover. The field can be plowed right up to the rock on all sides.—Sample 1520.

In making this trip a new sort of boulder was seen in many places—a white granular quartzyte, some of them two feet across. They show a plain sedimentary structure, and are rather fine-grained. They are hauled with other boulders into piles from the fields. They look like the usual "Winnipeg" limestone, of which not a piece was observed on the trip, although they do occur about the mouth of Crow creek.

Re-examination of Lignitic beds about Redwood Falls. In company with Mr. Park Worden, Capt. Dunnington and Mr. Terrill, of Redwood Falls, a number of workings in lignite beds in the vicinity were examined, particularly in the region of the valley of Crow creek. One of these was the very spot that I visited 15 years ago, now caved in, and nearly lost to sight. Another was visited with Mr. Peabody at the identical spot where Grant and Brousseau tried to get coal about 20 years before. None of these reveal anything new, nor give any reason to vary from the judgment and descriptions published in the second annual report, respecting their geological age and prospective economic value.

At Mr. Farrington's, on the bluff of the Minnesota near Crow creek, the lignite lies on the decayed gneiss, or on a somewhat stratified and re-arranged condition of it, due to the Cretaceous ocean. There is no conglomerate at the bottom—only this kaolinic material.

III.

Record of some Field Observations made in 1889.

Duluth. On the "Weller road," about a mile and a half from lake Superior (at Dulnth) and about two miles, by the road, from the business part of the city, is the spot that has been referred to *before as showing considerable amounts of red rock in the hills.

*Survey samples of N. H. Winchell, Nos. 1B, 46 .

Compare also Proceedings of the American Association for the Advancement of Science. 1881. Cincinnati meeting, *Typical thin sections of the Cupriferous rocks in Minn*

There is not so much of it as I had thought. It is very certainly the same rock, and has the same relation to the gabbro as that seen at Duluth and mingled with the gabbro at Rice's point. It is here in a scattered blotch, and in thin veins, in a fine porphyritic, gabbroloid rock—which last is like much seen in the city and environs of Duluth, but not so perfectly and coarsely crystalline as the Rice point rock. While the gabbro is quite different from the typical gabbro at Rice's point, it is essentially the same rock and of about the same age. Indeed it is almost possible to trace it continuously from one place to the other along the hill range that connects the two places. No. 1540 shows the gray porphyritic gabbro with a fine magma. No. 1541 shows contact of the red rock on the gray rock, 1540. No. 1542 is the crystalline red rock, with some light green spots. No. 1543 is chalcedonic quartz from this gabbro, as described below.

A very interesting observation is made in connection with this modified gabbro. On the weathered surface, where it also presents other irregularities of structure, resembling coarse amygdaloid, are seen white spots of silica. These spots are sometimes vitreous and glistening, as if of chemically deposited quartz, and in some central cavities quartz crystals form a drusy coating. But in other places this pure vitreous white quartz becomes granular, there being a gradual passage from one structure to the other, the granular increasing in distinctness and ease of disintegration toward a weathered angle, or toward the surface. Very rarely, small, subtranslucent areas as large as a wheat grain, or larger, can be seen, on the disintegration of the vitreous portions, which do not disintegrate, resembling amorphous or chalcedonic silica. The disintegrated granular portions, however, are not uniformly fine, and, in general, those portions are all coarser than the fine granular silica of the so-called chalcedonic silica of the iron mines. This observation shows:—*That the granular structure seen in silica, does not prove necessarily that the silica was of sedimentary or clastic origin*, since this is plainly the result of long weathering of chemical selica in these exposed cliffs.

These quartz masses do not show plainly a banded agate-like structure like the agates seen at Agate bay, or Gooseberry river, but in some of them there is a narrow band of harder, somewhat reddish, siliceous rock that surrounds them and forms an enclosing ridge that rises above the general surface. They vary in size from a pea to eight inches long, and while not very sharply angular, are not of the shapes of usual amygdules. Some of them have little cavities of irregular shapes in which small quartz crystals are seen projecting, and in others the white vitreous quartz is replaced, in marginal patches, or even in larger table-like protrusions, by a milky, opaque quartz, as mentioned above. Taken altogether it seems very likely that these quartz modules are indigenous in this gabbro-like rock, and are not of the nature of foreign or transported masses, but have originated in the gabbro by secretion, in a manner similar to the chalcedonic agates in the trap at the mouth of Gooseberry river (519).

At the Iron Mines at Tower. The designations of the various "mines" have been changed since the ownership changed. They are now known by number, viz:

No. 1 is what was known, and designated in our former reports as the Stuntz mine. It is the most easterly of those on the southern slope of the "north range."

No. 2 is what was formerly known as East Stone mine.

No. 3 is what was formerly known as Stone mine.

No. 4 is what was formerly known as Stone mine.

No. 5 is what was formerly known as East Ely mine.

No. 6 is what was formerly known as West Ely mine.

No. 7 is a pit on the former Tower mine.

No. 8 is what was formerly known as the East Tower mine.

No. 9 is what was formerly known as the West Tower mine.

No. 10 is what was formerly known as the Lee mine.

No. 11 is what was formerly known as the East Lee mine.

No. 12 is what was formerly included in the Breitung mine.

No. 13 is what was formerly included in the West Breitung mine.

Under the direction of Mr. H. A. Wilcox a systematic probing of the region has been carried on by diamond drill. This has resulted in the discovery of the existence of ore in some places not known before, and particularly near Tower in the "south ridge" or Lee mine. Some of the particulars of this drilling have been supplied to the survey. Indeed, through the courtesy of Mr. Geo. C. Stone, and of Supt. Bacon, every part of the mine, and all the records whether of drilling, assaying, mapping, shipping and grading, pertaining to the operation of the company, were thrown open to the writer for the use that might be wished for the purposes of the survey. Much assistance was afforded in making this re-examination, by the co-operation of the officers and the mining captains of the Minnesota Iron Company, and especially by the records of the drilling and some chemical analyses, the former by Mr. H. A. Wilcox and the latter by — Waters. Most of this detailed information is to be found in the special report on the iron ores of the state—

Bulletin No. 6, accompanying this report, but published separately. Subsequently the same courtesy was extended to the survey by the superintendent and other officers of the mines at Ely.

The purpose of this more detailed re-survey was to arrive, as nearly as might be, at a final conclusion, based on facts observed in the field, touching the question of the origin of the iron ore; and while that was a primary purpose, it was intended also to obtain more details of the actual manner of occurrence of the ores, the operation of the mines, and all the statistics that would be needed in making a full presentation of the iron ores in published form.

These observations were made in company with, and by the assistance of Mr. Horace V. Winchell who had previously examined many iron localities in the state, and had been exclusively at work on the iron deposits for about a year, and who was familiar with all the theories that had been proposed, and the obstacles that they met with. We subsequently published in *The American Geologist*,* a summary and preliminary statement of the probable result of the investigation, so far as it related to the origin of the ore itself, and the same view is presented again, more fully, with many facts that sustain it, in another part of this report.

At this place but little more will be given than the connected thread of successive field observation, with references to the illustrative rock samples, and some of the steps in the argument.

At the Lee mine, rock sample 1546. Here we collected some of the quartz crystals lining vugs in the dense hematite. These have not the clouded "chalcedonic" appearance of crystals formed rapidly, or of rapid chemical accumulation without crystalization, such as seen in the quartz in the jaspilyte. This kind of quartz in the ores of the district has frequently been described in the reports, and it has been supposed to have had a later origin than the jaspilitic quartz.

In the dump at the Lee mine (No. 10 as above,) is seen a reddish, earthy-looking jaspilyte, beautifully streaked as with sedimentary banding—No. 1547. It contains much pyrites, which is in bands and streaks coincident with the banding, this being apparently the form taken by the ore when accumulated under circumstances that gave the jaspilyte this earthy character. While this pyrite is disseminated minutely through the whole of this, yet in larger quantity it frequents certain bands. It is noticed that these bands cease abruptly along one side, when viewed on the

*American Geologist, vol. iv. p. 291. *On a possible chemical origin of the iron ore of th Keewatin in Minnesota.*

broken edge of the sedimentation, as if the conditions allowing its formation were wholly and suddenly changed in that direction. But on the other margin the pyritiferous bands fade out gradually in the midst of the other rock. This is the first instance in which any such variation, indicating an upper and a lower side to the jaspilyte in the process of formation, has been observed. It is probable that the line along which the abrupt change is introduced was the lower side of the pyrite band, and if the position of this impure jaspilyte within the mine, with respect to the strike of the ore mass, could be ascertained, it would furnish a key to the stratigraphic order of super-position of strata of the region–a desideratum which has not yet been supplied by actual observation, though it has been hypothetically deduced from a general view of the whole region. The principal pyritic streaks are about a quarter of an inch apart, but there are intermediate variations that also produce streaks, and on one side of the specimen collected the principal streaks are about three quarters of an inch apart, and somewhat undulating.

In other pieces this impure streaked jaspilyte appears as a pyritiferous impure hematite, and in others, still, the pyritiferous character is generally disseminated in the breccia of hematite and earthy jaspilyte. In larger cubes the pyrites is seen in a sort of soft greenstone.

1548. Breccia, a somewhat stratiform mass of fine pieces of red jasper, hematite, jaspilyte, quartz.

1549. Crystals that seem to be chalcopyrite, colored sometimes blue like erubescite (?) or bornite, Lee mine.

[On further examination these blue crystalline grains seem to be hematite tarnished.]

1550. Finely banded, whitish jaspilyte, part of a breccia, Lee mine.

1551. Hard hematite, with conspicuous included crystalline masses that appear to be chalcopyrite.

Going in the pit of the Lee mine, which is now 100 feet in depth, under the direction of the foreman (because we inquired as to the place of rock No. 1547 in the mine), we find the succession across the Lee mine to be as follows:

In fig. 5, which is an outline plan of No. 10, formerly known as the Lee mine, the star (*) indicates where the bedded rock, No. 1547, was found. Next north of it is breccia, with green stone material, with considerable pyrite and with the well-known white kaolinic, white substance. In the kaolinic material are sericitic, but rather hard and coarse-grained pebbles. There is an abrupt transition from fine, hard hematite to the rock 1547, but the contact, which can, with some difficulty, be traced out on the face of the wall, is tortuous and oblique. In the kaolinic material are also rounded pebbles of No. 1547. The general order of succession, across the mine, is thus, from north to south.

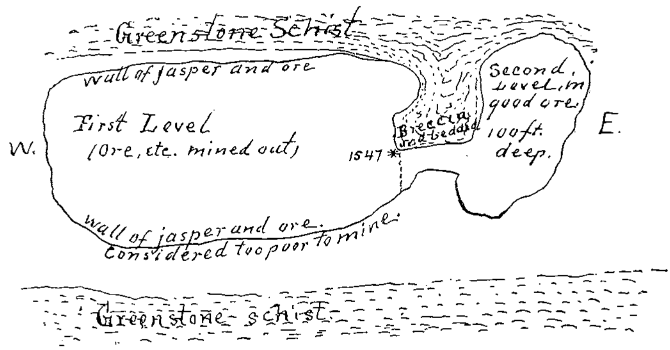


Fig. 5. Outline plan of the Lee mine.

1. Greenstone of the country, a chloritic schist, north side of the mine.
2. Breccia of greenstone, impure jaspilyte (rock 1547) and iron ore, with much pyrite.
3. Red, impure, sedimentary banded jaspilyte, somewhat resembling, in some places, a red shale, though it is always too hard and too heavy to be called shale. It is different from the well-known jaspilyte, as it shows no distinct chalcedonic silica, and only occasionally any distinct lines of hematite. It is not an important deposit, as to its amount, but apparently quite so as to its nature and origin, and its possible relation to the pure jaspilyte.
4. Fine, hard hematite, pure.
5. Main mass of ore; at its narrowest place about five feet wide, at the present face of the slope.
6. Jaspilyte, too poor to mine.
7. Greenstone schist, on the south side of the mine.

It seems as if the succession of formation progressed from the south to the north (or from No. 7 to No. 1), the impure jasper, No. 3 (or red shale) being formed by wash from No. 4, but rendered soft and impure by influx of materials from No. 7, or some other adjacent greenstone, and accumulated only in favorable nooks, followed by another greenstone (or schist), the latter serving, not only to break up and embrace in form of a breccia all the foregoing (Nos. 7 to 3), some of the inclusions being from the impure jaspilyte, some from the iron ore, and some from the jasper further south—but to contravene all the forces, whatever they were, that deposited the jaspilyte, and to substitute its own products entirely, with little or no modification, for the hematite and silica that had been deposited immediately before. If this schist (No. 1) were an undoubted, massive, homogeneous, non-clastic rock, it would be necessary to infer that the jaspilyte had been covered by a diabase overflow, and that in the bottom of the lava the materials of all the former strata had been involved in a brecciated condition. The occurrence of this breccia on the north side of the main jaspilyte mass, however, is not conclusive evidence of the later date of the origin of the northern side of the Lee mine, since there are jaspilyte masses in the green schist further north still, and some of them, when they were entire and continuous in one mass, may have supplied the material for the breccia, allowing the order of formation to have been from north to south.

Not far from Lee mine, by the old roadside leading to the Breitung mine and to the "location," on the top of the main hill, a large boulder was found of the Stuntz conglomerate, and its examination afforded some interesting facts.

1. This boulder contains pebbles of chalcedonic quartz (1552), some of them being several inches across.

2. It contains pebbles of gray, quartzose felsyte (1553 and 1554).

3. In these felsyte pebbles, which themselves are older than the boulder in which they are embraced, are rounded vitreous quartz pebbles which do not indicate any granular structure like the so-called chalcedonic silica.

4. Some of the pebbles of 1553, represented also by 1556, seem to exhibit an imperfect porphyritic structure, approaching that of "porphyrel" at Kekekebic lake, which they also resemble in nearly all other respects. This may point to some relationship between the Keewatin schists represented by the Stuntz conglomerate, and the porphyrel. The rocks, however, need a closer comparison.

The important result of this observation, however, is in the bearing it has on the nature of the granular structure of the jaspilitic silica. It has been presumed by some that the jaspilitic silica is granulated because of incipient decay, in the manner that the geodic silica in the gabbro near Duluth becomes granular. Not to mention here the evident difference between the granulation that is due to decay and that which is seen in the chalcedonic silica of the iron mines, it is sufficient to call attention to the perfectly intact vitreous condition of the quartz *pebbles within the pebbles* in this boulder, even when by fracture they have been brought to the surface of the boulder, and the perfectly characteristic chalcedonic granulation seen in the younger pebble of jaspilitic silica, No.

1552 above. That which is non-granular in this boulder is necessarily older, and has suffered more revolution of physical exposure, than that which is granular, for it is embraced within a smaller pebble, whereas the granular-silica pebbles are not so embraced. The granular silica pebbles are of the age (so far as respects the formation of this boulder) of the gray quartzose felsyte which incloses the non-granular silica pebbles. The inference is inevitable that it cannot be exposure and incipient decay which causes the granular condition of the jaspilitic silica.

We visited again the place that has been so many times referred to south of the Stone mine (pits Nos. 2 and 3) where,at the railroad cut, there is such a curious mingling of the green schist of the region with jaspilyte. I visited this cut with M. E. Wadsworth in 1886, to call his attention to the sedimentary interbedding of the schist and jaspilyte. There is a thin-leaved interstratification, and the jaspilyte is genuine, as such, not in "compound grains" as I had surmised. Cutting all this chalcedonic quartz are distinctly different veins of glassy quartz, of chemical origin, which has to be kept separate from the jaspilyte, some of them being six inches wide, and others not more than one-fourth of an inch—also geodic masses of the same.

Not only is the chalcedonic silica here interbedded, in lenticular sheets of the extent of one to three feet, (but frequently of less extent) but also there are small pieces disseminated through the schist, from the size of a pin-head to that of a man's fist, and also large masses having a red and purple color, placed somewhat irregularly in the schist.

There is also a siliceous base in the schist, which has this same chalcedonic grain, and some layers, (lenticular still) of a hard green rock, apparently more charged with this same silica.

As to this manner of occurrence of jaspilyte, I cannot make it consistent with any eruptive hypothesis—nor yet with sedimentary. The green schist is not here clearly of sedimentary structure, though there are variations in it to a more firm and siliceous character, that may be attributed to sedimentary accumulation. It appears to be best explained by supposing a combination of eruptive and aqueous agencies.

South of the Breitung opening, near the west end of the so-called "north ridge," runs a narrow streak of ore, about east and west, and since I saw it last it has been worked some. Westwardly it suddenly ceases, and a swampy patch supervenes, so far as can be seen in that direction. Toward the east it rises in the south slope of the main ridge, but as it is under drift deposits it cannot be traced but a short distance, and especially since where the work ceases in that direction it became rather narrow—say four feet, and seemed not to contain much ore. The structure of the green schists here dips northerly at 85° from the horizon, and the belt of iron and jasper oscillates in the schists on one and the other side of a right line.

This iron deposit is not first-class, but often pyritiferous, spongy and irregular, and apparently somewhat manganesic. The schists, at the spot where this belt crosses the road to the Breitung mine (No. 12), show a granular graywacke or sedimentary structure and origin, but not generally.

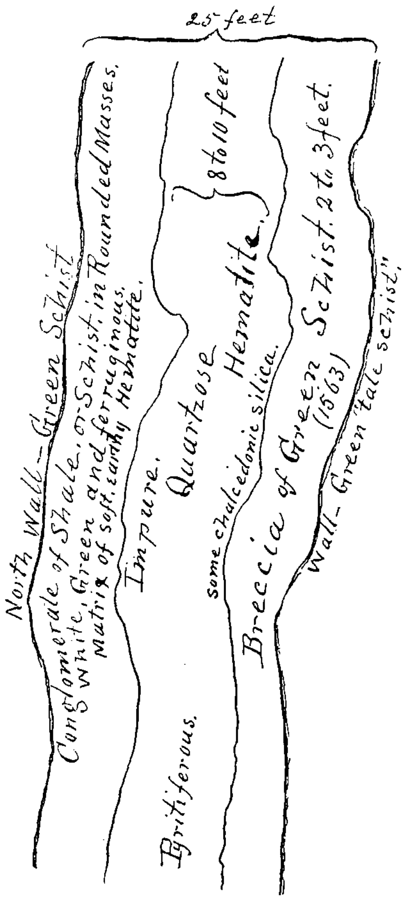


Fig. No. 6.
North and south section across ore pit near the Breitung, in the narrow ore belt.

On inspecting the order of changes in the stratification across this narrow iron belt where exposed in the cut at the eastern end of one of these small pits, a north and south section is obtained.

The narrow ore-belt, a section of which is seen in figure six, is very largely "derived" from some other larger bed. It is not exactly like the regular jaspilyte ore of the north ridge, inasmuch as it is fragmental and consists of rounded masses of both jaspilyte and green schist. This is conspicuously so in the breccia on the southern side and in the conglomerate on the northern side. Through the central part of the ore itself there is considerable pyrites, and on the southern surface of the ore-streak can be seen some original jaspilitic silica, where the hematite is hard. There is in this ore-belt, besides, a considerable amount of limonite, some of it in botryoidal surfaces on quartz crystals, and on hematite (1564). The limonite sometimes is further covered with a thin blue coat, and in some cases, especially in the vicinity of pyrite, there is a surface of coxcomb crystals, like hematite, covered with black, which last possibly is manganese.

A little to the south of this opening is a shaft for hoisting from this pit. It seems to have encountered flinty, gray to dark gray, jaspilyte (1565) judging from a large number of fresh, large pieces that lie near in the dump, (=866 B). Compare 1277.

The principal Breitung opening is very irregular, the direction of strike of the main ore mass winding about in the green schist from east to west so as to run nearly north and south, and abruptly ceasing, or beginning where not expected. Three things are noticeable in conjunction with the ore.

1st. It is heavily jointed, about horizontally, but this jointed part is better ore, and lies below a less jointed mass of jaspilyte, the line between them being characterized by a rotted belt (1566), running diagonally across the face of the wall and descending toward the west. This belt where most rotted is a breccia, so that it is easily dug out even by the hand, and the part that disappears by rotting consists of angular jaspilyte masses. Several other beds of similar soft and rotted material are seen in the ore, sloping toward the west, some of them being lenticular. The occasion of this rotting is the existence of the joint, into which water enters at the top of the ridge where it comes to the surface. The joint cuts everything, rigidly, whether breccia or not, and the breccia is most disintegrated by the moisture and frost. This is evident because, while the rotted belt in the main follows the sloping joint, the rotted belt widens out when it approaches and cuts a breccia layer or mass, in the main rock, and in other places the beds of jaspilyte are preserved entire or mainly so (when not breccia) across the rotted layer.

2nd. The surface of the ore abuts immediately on the greenstone, and the two surfaces are mutually slickensided, the greenstone, in one instance at least, having a fine, curved, semi-basaltic structure which at the junction is nearly perpendicular to the surface of contact. But in other cases the schist is red and hard along the contact for some distance, say for twelve or sixteen inches, and is closely cross jointed and broken, rendering it fissile in small angular lumps.

3rd. In the remaining ridge, which separate the Breitung from the Tower, the firm jaspilyte of which it consists is seen to contain, in several places, and in one place in a somewhat continuous layer traceable, with some interruptions, twenty or more feet, a breccia and conglomerate, one inch to four inches wide, in which are small rounded, or sub-rounded, at least water worn, pebbles of vitreous quartz (1567). There are, on both sides of this band, and in many places over this immediate vicinity, spots of breccia of chalcedonic silica, cemented by smaller breccia and pebbles, as well as by massive chalcedonic silica, all of which consist of the well known chalcedonic silica. But in the above vitreous silica there is no such fine grain as that which characterizes the jaspilitic silica. On the hypothesis of decay and disintegration, as the cause of the granular condition, why is not this condition seen also in these rounded vitreous grains which must be older than the chalcedonic silica in which they are embraced? This observation, like that already detailed on the pebbles of a large boulder seen not far from the Lee mine, negatives all resort to such hypothesis. In this pebbly jaspilyte the vitreous quartz grains, although obvious, are distributed rather sparsely, and the whole space they occupy, forming an irregular and interrupted vanishing belt, or layer, near the center of the main mass, is not more than three or four inches wide, and is not a noticeable band.

North of the Tower mine (No. 8), on the north slope of the north ridge, is a conspicuous shoulder-like protrusion of hard ribbon-jasper, with characteristic undulating and contorted bands. This jasper has five or six thin layers of green schist, or siliceous green schist, running through it, which were cotemporary with the formation of the jasper, since they are flexed with the red and white bands. These layers enter on the eastern border of the exposure and continue zigzag across it, but some of them pinch out or fade out before they reach the eastern border. One of them, after such disappearance, rises again faintly a few inches further west between the same colored bands that enclosed it further east. Figure 7 was sketched from this jaspilyte surface, with the design to indicate the forms and alternations that are exhibited, but no drawing can show all the contortions, and transitions, and alternations. The shaded part is one of the green schist bands. On close inspection it is found to be considerably modified from the typical green schist of the country, having a liberal percentage of silica—indeed it is so siliceous that were it not for the contrast it presents with the smooth, hard jasper it would hardly

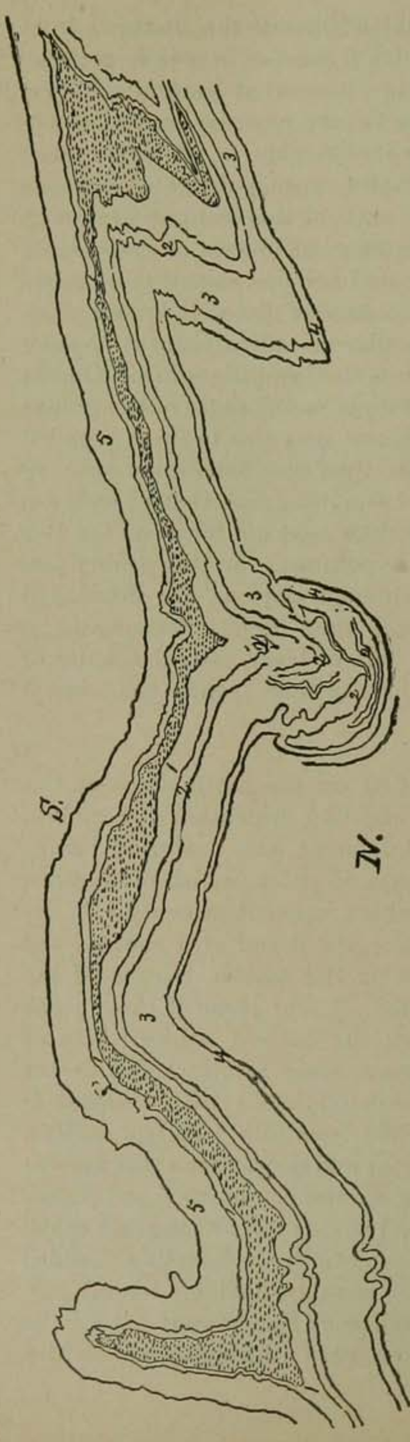


Fig. No. 7.—Green schist interbedded and contorted with the jasper ribbons.

be called green schist. Other belts of it, however, are less firm, and fade gradually into a softer (yet comparatively siliceous) light-green schist which cannot be mistaken for anything else than a part of the same rock as the green schist of the country. In case of all these green schist belts, though more siliceous than the average green schist of the country, they have disintegrated and been removed by the action of frost and vegetation, so that along their course across the jaspilyte knob, are little tortuous grooves due to their more rapid decay. A photograph was made of this jaspilyte surface, for which see bulletin No. 6.

In Fig. 7 the hooked expansion and sudden termination of the green schist band are in connection with, and a part of a general contortion in the jaspilyte which bends in the same direction, *i. e.* some of the thin layers do. The lamina of green schist, in an attenuated condition runs from the end of the hook some further and squeezes out gradually, and is lost, the jaspilyte walls coming together, so far as the appearance shows on the glaciated surface. Beyond the keel of the hook, however, in the general course of direction of the band, the green schist band appears again, and continues as far as the uncovered condition of the surface will allow of its being traced. Here the contortion is in the form of a swelling and lifting toward the north. The beds next south run along without showing any sympathy with this irregularity. There is also a similar protrusion and contortion seen on the north side near the center of the sketch. On the south side here also the jasper ribbons are not disturbed. These contorted protrusions toward the north must have formed before the formation of the succeeding jasper bands in that direction, because, not only do they not participate in the contortion, but easily pass by the protrusions with gentle swells and flexures that are independent of the close crumpling.

The shaded part (Fig. 7) is a belt of green schist. No. 1. at the left is a thin scale of brown jasper. Toward the right further it is gradually replaced by a thin scale, and further still to the right by a narrow ribbon, of hematite. In this brown jasper are lenticules of crimson jasper, presenting a maculated handsome surface. It also shows the fine lamination one thirty-second part of an inch wide which has before been mentioned as a characteristic of the jaspilyte ribbons. It also embraces thin sheets of hematite, and it is cut and cemented by transverse veins of crystalline vitreous silica. No. 2 is mainly hematite, but it has threads (really sections of sheets) of brown jasper; and at the central swell it is rendered impure, being broken, spread, separated by brown jasper sheets, and occupies, with the jasper associated with it, the whole of the swell. No. 3 is a broad band of brown jasper, that also shows the crimson jasper already mentioned. No. 4 embraces a group of hematite sheets interleaved with jasper, too thin and too close to be separately traced. No. 5 is a band of hematite which, at the east end of the sketch is seen to be flexed southward so as to embrace and to coincide with the pot-hook direction of the green schist, but toward the west runs independently of the sharp north-side hook at the west end of the sketch.

The inevitable inferences from a study of this rock surface are: (1) that the two substances, the green schist and the siliceous jaspilyte and the hematite were the product of practically identical forces acting on different objects; (2) that after the formation of some of the narrow bands they were disrupted and contorted before the formation of the next succeeding bands; (3) that the southern side was the lower, and hence the older side, and that the growth was from the south to the north (as the beds now stand); and (4) that there was usually a complete cessation of the deposit of the siliceous jaspilyte when the materials of the green schist were accumulating, and *vice versa*, but that occasionally, as illustrated in these rather hard bands of green schist, the two substances were deposited simultaneously.

Any theory that will satisfactorily account for the origin of the Keewatin iron ores, must allow for these inferences from the physical structure at the same time that it plausibly accounts for the origination of the elements of which the jaspilyte and the green schist consist.

The fact that there was some force concerned that could fracture the last-laid-down layer without disturbing the deeper ones, and that it was remittent, so that succeeding layers were normally formed and were not fractured is demonstrated also by a sketch made here showing an interrupted layer of brown jasper, the separated parts being surrounded by hematite and embraced in a continuous schist of it, one of the integral bands of the jaspilyte, but themselves also seamed by crystalline silica at other points. See bulletin No. 6.

I am impressed with the indications that this silica is arranged by sedimentation. What was its origin?—probably chemically precipitated; perhaps also that of the St. Peter sandstone, although they are very different in respect to size of grain and in age. The eruptions of basic rock that characterized the Keewatin must have made such changes in the chemical conditions of the oceanic water that silica and hematite were thrown down. Can that be shown? Then came, if not the minute crumpling, at least the general tilting which has brought the beds to verticality.

It is well known that the first attempt to extract ore from these hills was made by George R. Stuntz and John Mallmann. Mr. Mallmann happened to be at Tower at the time this examination was being made, and he kindly pointed out the spot where this working was done, and we made a photograph of the same. It is near the Lee mine, on the south side of the "south ridge," not far west of the east opening (No. 11). By the blast one large lenticular mass weighing three or four tons was rent from the south side of the jasper bluff. The photo is intended to show this. In the hole excavated by the men and by the blast bushes have now grown up, but the course of the drill is still visible on the upper side of the dislodged mass. The photograph is reproduced in Bulletin No. 6.

In the highest of the tunnels of the Tower mine, which discharges southward, and also the most westerly, and at the southern end, is a north and south rock-cut which seems to trans-sect at a more western point, the rock to which I have so often referred at the railroad cutting immediately south of the Stone mine, about half a mile further east. The mixed and generally interleaved condition of the green schist and the jaspilyte is the same, but at this place, as the cut is across the structure more can be seen of the relations of the two rocks, viz.:

1. The jaspilyte is contained in the schist in lenticular masses, and in thin interleaved vanishing sheets that have their sharp edges upward and downward. This is most manifest, in innumerable instances here within the horizontal space of thirty feet.

2. The jaspilyte is contained in similar masses that terminate east and west in the schist.

3. In the space of 22 feet, north and south on the face of this cut, I count 36 jaspilyte layers, varying in thickness from ¼ inch to 24 inches, all of them having at least 6 inches extent up and down, the rest of the rock being green schist, or jaspilitic red schist (or "shale" similar to rock 1547). Besides these there are some indefinite graywacken layers containing rounded pieces of jaspilyte as pebbles.

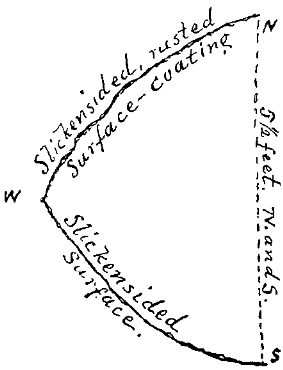


Fig. 8.
Western termination of a jaspilyte lenticule.

4. On the east side of the cut is seen the manner of termination of one of the larger lenticules of jaspilyte, in the midst of the schist, the exposed terminal end appearing unbroken near the track, though broken off at the top by the work of making the cutting. The shape of this western termination is represented by figure 8, which shows a section across the lenticule north and south.

5. Within two inches of this large mass, sketched above, was a smaller, apparently concretionary mass of jaspilyte, about 18 inches in its greater (perpendicular) diameter, appearing on the face of the cut to be entirely surrounded by the green schist and separate from the larger lenticule. Desiring to know whether it was connected with the foregoing large mass, I had a crow-bar brought, and, on making some excavation about it, the smaller egg-shaped lenticule was dislodged entire and fell to the ground. It left a continuous concave socket, the exact imprint of itself, and was coated and smoothed over its whole exterior in the same manner as the larger one, and was wholly independent and

separate from it. It is numbered 1568. It is sharper, in cross section, at the upper end than at the lower, and while about 18 inches in perpendicular diameter it is four and one-half inches thick (n. and s.) and eight inches wide (*i. e.*, east and west). Several small parts, broken from the upper end before it was dislodged, are also given this number. This shows that the egg consists essentially of hard chalcedonic silica, with a little hematite.

6. Within the tunnel, toward the north further, the green schist contains graywacken bands. In these are small pebbles of chalcedonic silica, but, in 1569, can be seen three (¼ in. thick) veins of chalcedonic silica crossing the structure of the green rock at oblique and varying angles. This was taken from the roof of the tunnel, about 15 feet from the southern entrance.

7. In No. 1568 the principal color-bands run across the face of the section, and are not wholly concentric. There is a series of accretionary bands, surrounding these and inclosing them with an outer rusty coating, which gives color to the supposition that the egg is wholly concretionary. These outside bands fade off into the green schist structurally and mineralogically.

8. The mass itself appears to have been a fragment dislodged from its native place, and, while perhaps not yet firmly rigid, to have been imbedded in the materials that now constitute the schist, and with them to have suffered the pressure and upheaval that have brought the beds into their present vertical position. If it had become rigid before it was placed in the schist, it might still, perhaps, have been compelled to take its ovate form by reason of pressure and the mechanical movements to which the beds have been subjected. Judging, however, from the general ovate form of all the jaspilitic lenticules, even the largest, it seems more reasonable to ascribe this shape to some forces or circumstances that attended its origination than to mechanical causes that operated afterward.

Revisiting the old pit of the Stone mine, and noting the so-called jaspilyte *dike*, illustrated in the 15th report (see p. 235), we observed another egg or jaspilyte similar to that just described, though this is partly disintegrated now so as to reveal an original brecciated structure, at least on one side. The harder part is perpendicularly banded jaspilyte. On its exterior is a layer of red shale about one and one-half inches in thickness. This egg is entirely isolated within the schist as shown by the following sketch, fig. 9, made on the spot.

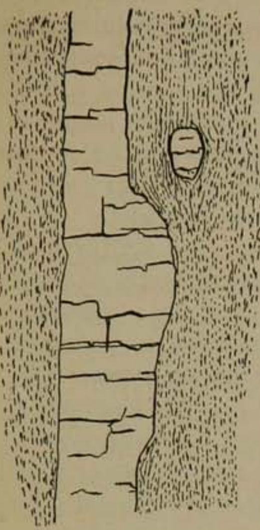
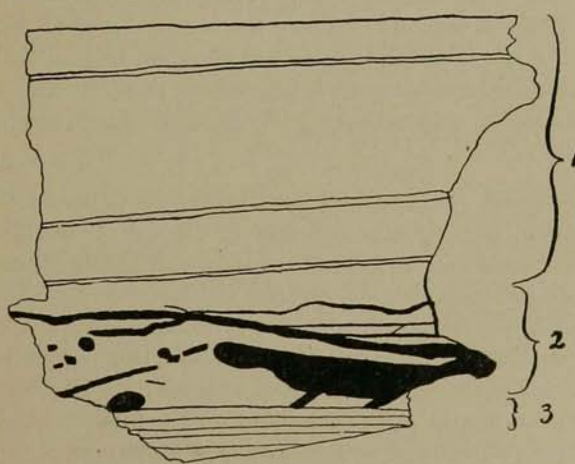


Fig. 9. Ovate lenticule of japsilyte at the Stone mine, adjoining the "kike" of hematite.

A very interesting and instructive observation was made at the Stuntz mine, or No. 1. In some of the large angular pieces thrown out upon the dump is seen a singular sort of conglomerate and breccia. It is illustrated by the following sketch, likewise made on the spot, fig. 10.

In No. 1, by far the predominating ingredient is white, chalcedonic silica. The same is true of No. 3. No. 2 seems to have been suddenly introduced in the midst of a silica-forming epoch, and as suddenly to have ceased. This interruption caused the coarse fragmental transport of masses from some previously formed green schist and from the previously formed brown jaspilyte. The green schist pieces are somewhat rounded, as would be expected from their softer nature, but the brown jaspilyte pieces are angular.



Explanation of figure 10.

1. White chalcedonic silica, banded with a little pure hematite.
2. Conglomerate and breccia of green schist and brown jasper. The black parts show the shapes of the green schist pieces.
3. White silica and hematite.

This indicates some rupturing agent that acted on both rocks. Indeed, there are many evidences that a frequently recurring force, whatever it was, interrupted the quiet accumulation sometimes of the jaspilyte and sometimes of the schist, and tore up sometimes only the last laid-down thin layer, and sometimes larger thicknesses of the formed beds, and removed them to smaller or greater distances from their native places. This force acted in a common manner on both the acid jaspilyte and the basic schist.

There is hence much reason to suppose that all three of the known agencies for rock-forming were intermittently at work and concerned in the formation of the iron ore, viz.: *Eruption*, to afford the basic eruptive material; *sedimentation*, to arrange it (in the main), and *chemical precipitation* in the same water, to give the pure hematite and the chalcedonic silica. What was the cause of the chemical change in the waters of the Keewatin ocean that brought about the precipitation of silica and hematite, is matter for further research. An ocean, universal as the Keewatin formation, charged with silica in solution, a hot alkaline ocean, on the outburst of volcanoes, might, perhaps, be so far heated, and evaporated, as to be compelled to deposit silica as a chemical precipitate. On the other hand the introduction of cooler currents into the heated region would disturb the equilibrium of saturated solutions, and hematite (or limonite) might be the resultant precipitate. There is reason to believe the earthy, or semi-crystalline, schists of the age of the Keewatin are world-wide, and that, therefore, the ocean everywhere had, in general then, as now, nearly a constant character, only as modified by local or wide-spread volcanic agents.

By the railroad, just south of the Tower pits (Nos. 8 and 9), is a light greenish, novaculitic rock which dips N. 75 to 80 degrees (1557), It passes into graywacke. It is also highly siliceous with both chalcedonic and vitreous quartz, and has a fine white ingredient that gives it a feebly talcose feel, the last being the same element that we have called sericitic. The soft, light green (or white) mineral varies in amount from layer to layer, so that some of the sheets are smooth and soft throughout, and schistose, others being more like graywacke, and others almost a quartzyte in which the vitreous quartz grains can easily be distinguished from the chalcedonic, by their dark color, that is, by their absorption of light which falls upon their fractured surfaces.

I met Mr. W. G. La Rue, of Barraboo, Wis., and he gave me further evidence that there are really two quartzytes concerned, as already represented by me,* in the geology of the Gogebic iron region. One is that which is the foot-wall of the Colby and Aurora mines, and the other is that which Mr. La Rue describes, viz.: North from the Colby mine, near the bluffs of the gabbro range, which there are plainly visible rising as a series of hills within a mile or less of the village (Bessemer), he was employed to explore for ore by shafting for some parties who thought there was ore near the gabbro. He said that under the gabbro he found a quartzyte, and a sandstone, the two differing only in induration, one being more easily excavated than the other, both consisting of crystalline quartz. He shafted under the quartzyte in a conglomerate of iron ore, which seems to be comparable to that found in a similar situation at Ishpeming, Mich.,** and at Cascade near Negaunee, and after a time he found that the conglomerate turned almost at a right angle toward the north. He did not seem to know what was under the conglomerate, but he told me he found the quartzyte and sandstone together 235 feet thick. This was in the sw¼, ne¼ sec. 10, 47-46, Michigan. This is apparently the unconformable conglomerate and quartzyte that I noted at Bessemer, at the railroad, in a small exposure, in my sixteenth report.

IV.

The Age of the Gabbro.

In attempting to correlate these observations with those which have been made and recorded in previous years, there is some difficulty in fixing the stratigraphic place of the gabbro eruption. It was inferred by the Wisconsin geologists that the gabbro sheet was the bottom layer of the great Cupriferous formation, or Keweenawan, and this was accepted and has been followed unquestioningly by the writer in all previous reports and discussions of the crystalline rocks of the state. The age of the great Cupriferous formation, with its traps and conglomerates, in part at least, has been established, with increasing evidence and positiveness as on the horizon of the typical New York Potsdam—at least at the horizon of a quartzyte which overlies the Animike of the northwest.

Thus the gabbro sheet was carried to the same age. When the gabbro was found to be interbedded with a quartzyte in northeastern Minnesota, and to lie upon and overwhelm it, (the Pewabic quartzyte), it was a necessary inference that that quartzyte was the

* See 16th Annual Report. pp. 55-6.

** See the 16th Annual Report, pp. 44-47.

equivalent of the Potsdam—or at least of the bottom quartzyte of the Cupriferous—and hence must lie over the Animike, although at no place could the Animike be seen interposed between it and the gneisses of the Giant's range. When it was found that this quartzyte which is the principal iron horizon of the Mesabi range, shows evidence, in the region eastward from Pokegama falls, of passing below the body of the Animike strata, necessarily carrying with it the gabbro sheet, the idea that the gabbro has possibly been put into a wrong position is brought out prominently before the student of northwestern stratigraphy, and he is disposed to call in question the datum from which some important conclusions have been drawn.

The gabbro sheet itself is a wonderful formation, both in geographic extent, and in vertical thickness. It is also wonderful in the diversity of lithological variations that it displays—*i e,* when it approaches the characters of a normal doleryte, or when it is interstratified with beds of sedimentary origin, or when it is modified by contact with them. Yet its persistence under erosive and atmospheric agents, and its great volume, causes it to appear prominently and suddenly, and frequently, giving it the reputation of greater area and importance than it deserves. This is rendered more marked by the fact that its line of outcrop is characterized by heavy drift deposits which have covered up the less persistent formations and hid from inspection their true relations both to the overlying and underlying strata. It was hence a very natural conclusion that its advent was the opening scene of that succession of eruption and sedimentation which is displayed in the Cupriferous formation and that the whole should be grouped together under that single designation.

It is the design of this chapter to call attention to some facts that indicate that the gabbro lies below the Animike, (Huronian black slate), in great part, and that the later trap eruptions, continuing through the Animike and the Potsdam, (*i. e.*, the Huronian quartzyte), probably constitute the age and the strata of the Cupriferous formation—the "Keweenawan" of the Wisconsin geologists. In other words it seems as if the Keweenawan series, in its full scope, embraces not only the age of the Huronian, (Potsdam), quartzyte, but also of the black slates of the Huronian that underlie the quartzyte.

1. The most important and significant fact that bears on the stratigraphic position of the gabbro, respecting its relation to the Animike black slates, is its occurrence along a wide extent, reaching from Gunflint lake southwestward as far as to the railroad

crossing at Mallmann's, (at least), *next to and immediately south* either of the gneiss of the Giant's range or of the "greenstones" of the Kawishiwin, without the appearance of any of the black slates between them. There is an appearance of *quartzyte*, with olivine grains and with magnetite, geographically between the gneiss and the gabbro, the same being unquestionably the Pewabic quartzyte seen near Gunflint lake. This quartzyte sometimes is impure and limonitic, and seems to be the chief iron horizon of the Mesabi range. This near conjunction (which is sometimes apparently an exact contact) of the gabbro with the gneiss, and the absence of the Animike proper between them, has been supposed to be due to a local overlap of the gabbro beyond the strike of the Animike, covering it from sight, the idea being that the gabbro flowed back northward over older formations, and came on to the gneiss.

2. Although there has not yet been any careful microscopic examination into the differences between the typical gabbro (for instance that seen at Rice's point, near Duluth) and the eruptive rocks that overlie the Animike black slates at Gunflint lake and eastward to Pigeon point, it has been noted that there are macroscopic distinctions which ought to be explained in case of a supposed parallelism of one rock with the other. The supposition has been that they are stratigraphically and chronologically the same, and that the differences were only local and unimportant. It was this assumed parallelism and the evidently later age of the eastern outcrops (the "crowning overflow" of the Animike) which has led to the placing of the gabbro later than the Animike. There is absolutely no other evidence. If these two eruptive rocks are not contemporary there is not only no reason against but considerable evidence in favor of placing the typical gabbro (such as at Rice's point, and at Little Saganaga lake) below the body of the black slates.

3. Boulders of characteristic gabbro and of red syenite, and of quartz porphyry, occur abundantly in the later "traps" of the Cupriferous. The quartz-porphyry pebbles are so abundant as to constitute the well known thick beds of coarse conglomerate; and quartz-porphyry layers or lenticular *sheets* are interbedded between the trap sheets. This quartz-porphyry in some cases appears to have originated in its present condition of interleaved sheets during the time of the Cupriferous. This is observable at the mouth of Baptism river, and at the Great Palisades. At these points, however, owing to the proximity of bosses of gabbro rising above the rest of the country about, it is certain that those portions of the Cupriferous which contain the original quartz-porphyry beds, are near

the bottom of the formation. This is further shown by the existence, in the same region (at and near Beaver Bay), of large boulder-masses of gabbro in the trap flows, evidently derived from the neighboring gabbro hills. From this point, northward to the gneiss of the Giant's range, nothing is visible, in the form of rock *in situ*, except gabbro, or some "muscovado"-like rock described at some outcrops somewhat further west* by H. V. Winchell. The region is not fully explored, but it appears from all that is known, that there is nothing to be found of the typical, thin black slates of the Animike. It is as reasonable to infer that they followed after the gabbro flood, as that they preceded it. In case they followed after it, their typical characters were destroyed in this region by the frequent outbursts of igneous eruption, and they blended with the tuffs and shales and basic sheets that constitute, on the north shore of lake Superior, the lower portion of the Cupriferous formation. In case they preceded they must exist buried below the gabbro, as hitherto supposed.

4. In further consideration of the possible infra-position of the gabbro mass, below the Animike proper, attention should be given to the record of the deep well at Duluth, as given in Bulletin No. 5, of the survey. The interpretation of the record, given on page 34, shows, below the gabbro, (which is found to be 220 feet thick), quartzyte and conglomerate beds interstratified with imperfectly characterized gabbro, the whole having a thickness of 67 feet. Then followed trap sheets, and fragmental tuffs, for a thickness of 89 feet. Then follows what was thought to be the Animike, "evidently the Thompson slate formation." In the light of the foregoing (Nos. 1, 2 and 3) however, and on reviewing the descriptions given of the drillings of this well (pp. 31-34), the writer considers it quite doubtful whether "the Thompson slate formation" is on the horizon of the Animike of the northwestern part of the state. The existence of a minutely granular condition in the quartz (Nos. 39, 46, 50), recalling the "chalcedonic silica" of the Keewatin, and of a distinct slaty cleavage not due to sedimentary bedding (Nos. 28, 36, 37, 53), and of hydromicaceous or sericitic schist (Nos. 28, 30-39), and kaolinic itacolumyte (No. 41) noticed and recorded when the writer was impressed with the expectation of finding Animike characters, must be admitted to point to the Keewatin schists and graywackes. There are other coincident descriptions of the outcrops about Thompson, to be found in the tenth annual report (pp. 12-31) which throw doubt on the supposed parallelism

*Seventeenth report, p. 90-91, Samples 387 (H).

of the Thompson slates with the Animike of northwestern Minnesota, viz:

1. Folia of quartz and slates, or schists interbedded, (p. 12, No. 454, p. 16, No. 466, p. 17, No. 472), is a character not known in the Animike.

2. There is a conspicuous perpendicular slaty cleavage in all parts which is not dependent on the sedimentary structure, a character not seen at all, or rarely, in the Animike in the northwestern part of the state.

3. The clay slates are frequently pyritiferous, (p. 18, No. 473.)

4. Feldspathic graywacke (often called gray quartzyte in the original descriptions) is a conspicuous feature in the strata north from N. P. Junction (p. 28, No. 504).

It is only intended here to make record of these reasons for hesitating before accepting the parallelism of the whole of the Thompson slates with the Animike of the northwestern part of the state, notwithstanding the fact that it has been accepted hitherto, both by the Wisconsin survey, the U. S. geological survey, and by the Minnesota survey.

5. On the supposition that the Animike black slates are involved in the Keweenawan, and, while overlying the gabbro, lose their typical characters at points further southwest, the interbedding of the Animike with beds of trap-rock, which is a common feature about Gunflint lake and on the shores of Loon lake, is easily explained, and indeed falls into place as one of the to-be-expected facts of such a period of recurring eruptions. It also obviates the necessity of a supposed change in the character of the eruptive rock, *i. e.* that the gabbro of Rice's point and Little Saganaga lake becomes, on Pigeon river, the dark or greenish trap-rock and the dioryte which inter-bed and characteristically overlie the Animike, forming the well-known "crowning overflow" of that region.

V.

Further Observations on the Typical Huronian, and on the Rocks about Sudbury, Ontario.

In the summer of 1889, on the occasion of the Toronto meeting of the Geological Society of America, the opportunity was improved, both in going and in coming, to extend a former acquaintance made with the rocks of the region north and east of lake Huron.* A resume of these observations was read before

* Compare the sixteenth annual report of the Minnesota survey.

the Minnesota Academy of Natural Sciences at the October meeting, 1889. In order that the bearing of the following facts and interpretations may be understood by any who have not given close attention to the developments of Archean geology in the northwest during the last few years, a brief resume may be the best introduction.

It is well known that in the term Archean are included two groups of rocks, the Huronian and the Laurentian.* These terms are of long standing, and have been used in the geological literature of nearly all parts of the world, wherever geological research has been carried on in the oldest rocks. They were proposed by the Canadian geologists in 1855, and were in a few years adopted by the geologists of the United States, and they are yet found in nearly all of the text books of geology in use in this country, with the signification that the Canadian geologists have given them. It is not necessary to say here what inconsistencies were involved in this course of accepted nomenclature, nor what injustice was rendered to American geology by American geologists, nor what were the motives that apparently actuated the leaders of American geological opinion thirty or forty years ago. It is only necessary to say that *Huronian* was in conflict with *Taconic*, and that *Archean* was in conflict with *Azoic* as well as *Atlantic*, names that had been proposed earlier by United States geologists.

With the revival of work on the older rocks in the northwest, about ten years ago, it was found that the original Huronian of Logan and Murray had been amplified, by the reports of the later assistants on the Canadian survey, by an important extension of the names downward, over many varieties of rocks not mentioned in the Huronian region by those who first described the Huronian formation, and even over all the stratified, or schistose formations, down to the massive gneisses and syenites which are called distinctly *Laurentian*. This extension had also been accepted by many, if not by all, geologists of the United States. This was true of the late surveys of Michigan and Wisconsin, and of the earlier reports of the Minnesota survey, and was maintained, but haltingly toward the last, by Prof. R. D. Irving up to the time of his death.

In order to get a correct understanding of the character of the Huronian rocks of the original Huronian area, several recent reexaminations have been made of the area described and mapped

* C. H. Hitchcock has called attention to the fact that G. W. Featherstonhaugh proposed the term *Atlantic* for these rocks many years before Prof. Dana introduced the term *Archean*, and before Foster and Whitney employed the term Azoic. See *American Geologist*, vol. V, p. 199. Also compare *Geology of New Hampshire*, vol. 1, p. 525.

by the Canadian geological survey. The first was that of Prof R. D. Irving, who came to the conclusion that the so-called Animike formation of Minnesota and Thunder bay (in Canada) is the equivalent of the original Huronian. But, unfortunately for the cause of correct nomenclature, Prof. Irving, who had embraced the expanded Huronian in his Wisconsin work, so continued his trip beyond the limits of the original Huronian, that he found, eastward from Algoma, a series of rocks which he thought also belonged in the same series with those at Thessalon, and so verified (?) his classification published in the Wisconsin report. Hence, while correctly assigning the real Huronian to its western equivalent (the Animike slates and quartzytes), he failed to see that outside of the mapped Huronian of Logan and Murray the name had no right to be extended over a different formation, for eastward from the mapped area another formation at once begins and hence, also, he continued to maintain that the Animike could be extended downward so as to cover all the lower schists and graywackes and iron ores of the Northwest.

Prior to this an unconformity and a profound change in lithology had been discovered between the Animike formation and the schists below it, in the vicinity of Gunflint lake; and, at a later date, those schists had been examined in the region of the Lake of the Woods, and while placed doubtingly in the Huronian by G. M. Dawson, and by Bell, had by Mr. A. C. Lawson been given a new name, (Keewatin) who exempted them, questioningly, from the Huronian system, showing that they pass unconformably below the Animike which had been said by Prof. Irving to be the real equivalent of the Huronian on the north side of lake Superior.

In the sixteenth report of the Minnesota survey will be found two other recent descriptions of the original Huronian rocks, from an examination made in the summer of 1887. Here the Huronian formation is distinctly limited to the strata described at first and named Huronian by Logan and Murray, and the name given by Dr. Lawson for the underlying schists (Keewatin) is adopted unqualifiedly, and extended over those schists in Minnesota. The same classification had been adopted also in the fifteenth report of this survey, but without the authentication that comes from a fresh examination of the old data.*

As the current idea of the Huronian, as at length extended by the Canadian geologists, began to be questioned, several re-affirma-

*The writer has reviewed the history of the Huronian system as expounded by the Canadian geologists, in the AMERICAN GEOLOGIST. *Methods of stratigraphy in studying the Huronian.* Vol iv. p. 342.

tions of its correctness have been published by Drs. Selwyn and Bell. It was in the light of these discordances that some recent re-examinations have been made, and the following notes were recorded when on a joint excursion with several geologists from the Toronto meetings of the American Association for the Advancement of Science, and of the Geological Society of America.

North Bay.—The rocks about North Bay,* on the northeasterly shore of lake Nipissing, placed in the Laurentian by the Canadian geologists, consist of dark-colored, micaceo-hornblendic gneiss, or gneissic schist. They are distinctly bedded by sedimentation, the characteristic belts of which run parallel for long distances. They are generally fine-grained and often red-weathering, recalling by this, as well by their structure and mineral composition, some gneisses seen and described by the writer in 1886,** on the Kawishiwi river. These are massive, fine-grained, red, very siliceous beds, as if from a quartzyte, but the most of the rock is closely laminated varying from very micaceous to very orthoclastic. The strata stand about vertical, but generally show some inclination southward—but sometimes northerly. The strike is about NW. and SE. Some of the gray gneiss (1573) which weathers reddish (1574) becomes contorted in some places and infolds, unconformably, masses of a dark rock very different from the gneiss (1575). These masses are wrapped round continuously with unbroken, but curved laminations of gneiss, the laminæ, at some distance from the enclosed masses, becoming straight again, and running in their usual course. These contrasted foreign enclosures have a different aspect, and a different composition from the micaceous belts of the gneiss. They are both micaceous and hornblendic, but mainly hornblendic; non-laminated and generally containing multitudes of fine crystals of cinnamon-garnet. In some places these masses are very large, and cannot be seen to be enclosed, but cut off the gneiss and replace it in large areas. The geology in general here recalls that of Northeast cape in Bassimenan lake (fifteenth report, p. 358), as well as that mentioned on the Kawishiwi river. The rock has been plastic *in situ* and molded about masses of foreign intruded rock, apparently a basic eruption, but has not been molten and extruded. In general the horizon to which it would be assigned in the Minnesota scale, would be near the bottom of the crystalline schists (the Vermilion series), or very near the Laurentian gneiss. It is very probable

*The rocks about lake Nipissing have been described in the Canadian reports by Alexander Murray, for the year 1854, for the year 1855, and maps of the atlas accompanying the volume.

**See the fifteenth report, Minnesota survey, p. 353.

indeed that rocks like these have been included in the Laurentian in some of the descriptions and map-coloring in our reports. Since it graduates, in Minnesota, conformably on the one side into typical gneiss containing very much less mica, which would be placed unhesitatingly in the Laurentian, and, also, on the other hand, fades out by the loss of the black mica, and by the acquirement of a sub-crystalline and finally a fragmental texture, into the typical rock of the Keewatin, it is evidently only an arbitrary line of separation that can be drawn distinguishing it definitely from one or the other. The principal difference between it and the Keewatin consists in its more nearly perfect crystalline structure. The principal difference between it and the greater portion of the Laurentian gneiss in Minnesota consists in its greater percentage of black mica. The prevalence of the black intrusive masses oc-

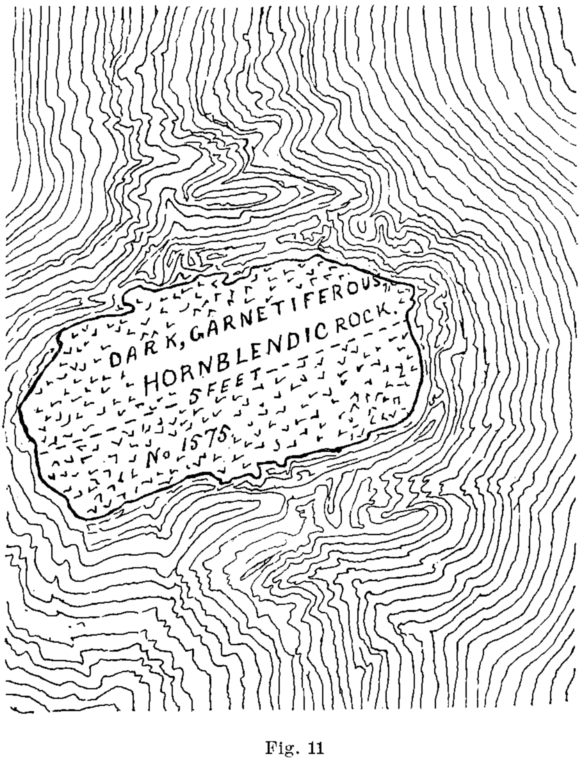


Fig. 11
Included hornblendic mass at North Bay, causing contortions in the gneiss.

Rock Samples obtained at North Bay are numbered as follows: 1573. Gray gneiss, the general rock at North Bay, after the weathered surface is removed. 1574, Reddish weathered gneiss, a surface condition. 1575, Hornblendo-micaceous and garnetiferous dark rock embraced in the gneiss (see figure 11) as foreign masses, and as large areas, the laminations of the gneiss being wrapped about them entirely and roughly conforming to their exteriors.

curring transverse to the strike of the gneiss, and in a manner involved with the gneiss, showing a mutually plastic condition of the two, is a characteristic of the Vermilion series about where the transition to the Laurentian occurs with an *eruptive unconformity*, the foreign intrusive rock being the dark, hornblendic masses and not the gneiss. The manner of occurrence of one of the smaller hornblendic and garnetiferous dark masses was sketched on the spot and the same is represented on page 51 (Fig 11). This was near the public school house at North Bay.

Wahnapitae. A sample of that which is here called Huronian by Dr. Selwyn is numbered 1576. At this point the formation changes from the Laurentian to the next higher, or supposed younger, formation. The train stopped but for a moment, but with difficulty a small sample of the country rock was procured. On examination it was found to be of a hydro-micaceous schist, silky-sericitic, evidently a part of the Keewatin. Subsequently Dr. A. C. Lawson re-examined this point, in order to get a better idea of the relations of the formations, and according to verbal description from him, there appears to be an unconformity of stratigraphy at Wahnapitae. similar to that at Penokee gap, Wisconsin; at the immediate contact the lower rock is the fine, micaceous gneiss, or mica schist, probably belonging to the series seen at North Bay, and the upper rock is quartzyte and gray argillyte interbedded.

At the Stobie copper and nickel mines, about three and a half miles north from Sudbury, there is a large exposure of greenstone, coarsely fibro-crystalline with hornblende (1579), seen south of the mines rising in high ridges and domes, resembling the ridges of the Kawishiwin greenstone of Minnesota (see the 17th annual report), though much more coarsely crystalline. This lies below the rock that contains the copper and nickel ores, and was fruitlessly penetrated by a costly shaft in pursuit of the ore-bearing rock several hundred feet. The present mining is done in a quartzyte (?) or at least a quartzose, apparently fragmental rock, which is superficially buried under a thick deposit of rusted debris, or gossan-cap, the result of its own decay. The ore permeates this gray granular rock in the form of sulphides which in this superficial layer is converted to oxides and carbonates. The mines are still not deep, although some tunneling has been done in the hillside. Outwardly the resemblance of the lithology of the lower rock (1579) to some of those described in northeast Minnesota belonging to the eruptive portions of the Keewatin is so great, that it is reasonable to suggest that it represents the lower formation. But the quarried rock cannot be assigned with any certainty to the same horizon. Its resemblance to some of the lower feldspathic, gray quartzytes seen in the Animike (Huronian), and its manner of occurrence in a low bluff apparently dipping at a low angle away from the lower greenstone, as well as the similar occurrence of abundant sulphides of iron (and nickel ?) in the lowest parts of the Animike west of Gunflint lake, caused me to regard the ore-bearing rock, on lithological evidence, as belonging to the true Huronian, and hence as unconformable on the other. Samples of the ore are 1578, and of the ore-bearing rock 1577.

At the Copper Cliff mine, three and a half miles s. sw. from Sudbury, according to Dr. Selwyn a dioritic dike (1581 and 1584) runs through the country, and the ore is associated with that. The next rock, on the north, is a red felsyte (1583), and the relations between it and the mined rock were not made out by anything I saw in the short time we were on the spot. The red felsyte becomes protogenic, or granitic, and also has fine black mica-scales developed in it in other places. The ore of this mine is represented by No. 1582. Eastward from the mine is a small knob of red felsyte, and next, about ¼ mile from the mine, is a knob of coarse conglomerate in which there are large boulders of red-weathering felsyte like that at the mine, also of laminated fragments of a grayish rock like a fine-grained graywacke or coarse argillyte, and probably others. The matrix is gray and finely siliceous, of which No. 1585 shows an average.

At 1½ miles from Sudbury, toward Onahping, the train stopped for the examination of a peculiar rock (1586), recalling, but not identical with, the hornblende-porphyry of Kekekabic lake (No. 751), but having much coarser crystals, and a more evidently conglomeritic original structure. At ¼ mile further nw. this conglomerate is more crystalline, the matrix being reddish-weathering felsyte (1588), and the included masses being of a dark basic rock probably originally eruptive. In places this felsyte becomes granitic, and the large dark fragments appear as boulders and included masses more or less modified in shape, embraced as in a once plastic or molten rock. The aspect in such cases is much like some Laurentian, and if it were to be found to extend over a large area with these characters, it would probably be assigned to the Laurentian by any geologist. This illustrates one of the difficult problems involved in the use of the term Laurentian. This rock is in the midst of what passes for *Huronian*, and is derived from a fragmental rock which is like many seen in the "Huronian" of the region. It assumes first a porphyritic aspect, then it is felsitic, weathering reddish with a pronounced orthoclastic ingredient, then, with a coarser grain, it appears like an eruptive granite embracing masses of foreign basic rock. This is similar to some observations that have been made in Minnesota in the Keewatin, and particularly on the upper waters of the Kawishiwi river. Similar transitions have been observed in Michigan. *

At the Murray mine the ore (1589) is in a conglomerate, disintegrating and limonitic.

At Vermilion lake (*i. e.*, at the crossing of the Vermilion river), is a repetition of the falls, ridges and rapids seen at Thompson, Minnesota, the whole being manifestly of the same age, and supposed to belong to the Animike or true Huronian. The dip of these slates is 45° towards the S. Dr. Bell stated that the train, before arriving at Vermilion river, had passed over these slates for about five miles. viz; through a very flat and good agricultural tract, indicating a profound change in the underlying rock, inasmuch as, up to the place of entering on these slates, the country had been very rough, with frequent exposures of the rock. The slate is black, (or purplish black when dry), generally fine grained, yet with some evident grains of quartz, (No. 1590). In it are some curious calcareous bunches, or "concretions," which recall the soft masses in which Dr. T. Sterry Hunt reported evidences of a "keratose sponge," found near Thompson, Minnesota. Some of these masses are two feet in diameter, with rounded outlines, presenting on the weathered or glaciated natural surface a striking contrast with the rock which encloses them. They are locally designated "snow-shoe tracks." This brownish, calcareous material is represented by No. 1591.

From the Vermilion river, traveling still northwest, we passed on to a lower series of strata, the dip being to the south-southeast. This is a "slate conglomerate," (1592), and causes an immense ridge, 150 feet in hight, more or less. Into this rock Dr. Bell states that the slates at Vermilion river graduate conformably, and indeed so they seemed to do; and in this respect the succession seems to be like that seen in the region of the original Huronian northward from the Thessalon valley, as described in the sixteenth report of the Minnesota survey. This "black slate," therefore, and the underlying "slate conglomerate" should be considered as portions of the Huronian as described by Murray and Logan.

Immediately after passing this ridge of "slate conglomerate," the average surface level subsides again, and the country is more even. But the rock that succeeds to the slate conglomerate toward the northwest, is mainly a reddish felsyte, similar to that seen

* Compare the 15th and 16th Annual reports, Minnesota survey.

in the vicinity of Sudbury, and necessarily underlying the foregoing slate and "slate conglomerate." It is also broken up into irregular small knolls, and presents a confusion of dip and strike that contrasts strongly with the regularity of dip and strike maintained by the overlying formation. This formation seems to have supplied many of the felsitic and granitic boulders seen embraced in the slate conglomerate. There was no opportunity to make search for the immediate contact of the "slate conglomerate" on this rock, but if the observations that have been made recently in the area of the original Huronian, and on the Animike in Minnesota, be taken as guide, there would be found, on making such a search, a distinct overlap unconformity at such contact line.

From this point (Onahping) the excursion car turned back, and although it was planned to make a stop at Wahnepitae bridge to allow those interested to inspect the contact there between the Laurentian and the "overlying" formation, a heavy and continuous rain interfered, and the car returned directly from Sudbury the same evening to Toronto.

After this excursion I had the pleasure and the benefit of a further examination of the original Huronian région in company with Dr. A. R. C. Selwyn and Dr. A. C. Lawson. We walked from Algoma to Serpent river along the Canadian Pacific railway,noting the rock cuts, and the following is the general result of my own notes.

Quartzyte extends from Algoma to about one mile east, when a greenish slate (1593) appears with a dip s. 10° w, 45°—65°. This is fine grained and sometimes cut by dioritic dikes of epidotic rock, like that at Bruce. Next appears at 1½ miles from Algoma,a dark-gray roofing-slate (1594), the cleaving and bedding dipping southerly at an angle of about 75°. Below this is an immense stratum of "slate conglomerate" (1595), (3d of Logan's map of 1863), which is charged with boulders of various kinds of rock, the most conspicuous being of red granite. We then met with a soft fissile argillyte (1596) which hardly has any remaining sedimentary banding, and in it are elongated lenticular sheets of silica, apparently chalcedonic (1597). This resembles some seen in the Keewatin but there could be seen no contact, as the exposure is in the form of an isolated ridge which passes below the drift on all sides, so far as ascertained. It seems to be not a part of the argillyte before mentioned. This stands, in some places, nearly vertical. Then comes on a great quartzyte member (1598), but this is quite different from that seen at Algoma, and in the Thessalon valley. It is uniformly very fine-grained, and is apparently Logan's "gray quartzite," the lowest included by him in the Huronian. It is at any rate the same as the *Missasaugui quartzyte*, so-called in the 16th Minnesota report, which was there supposed to be Logan's lowest quartzyte. It is gray within and weathers red. The railroad swings back and forth across the ranges of this rock, following the easiest route, and affords some good opportunity to examine it. It exhibits important differences from the upper Thessalon quartzyte. It is interbedded with abrupt transitions from hard, apparently chalcedonic (?) silica, or quartzyte, to fine chloritic schists, the beds of the quartzyte being from a foot to two feet in thickness, and those of schist from two to eight inches. This extends for at least four miles, with some interruptions, the road passing in general at an oblique angle across the strike of the formation. The beds are for long distances straight and parallel. At a distance the face of the rock recalls the regular and straight furrows of a plowed field, the schist weathering and washing out easier than the quartzyte. Such a view is seen on the south side of the track about four miles from Algoma.

At a point still further east the conglomerate recurs by the track. Here it holds quartzyte pieces like the quartzyte just mentioned, and also others of red granite, and numerous pebbles of bluish vitreous quartz. It also embraces pieces of nearly black argillyte (1599) which is soft and has a nearly white streak.

After an interval of nearly a mile and a half of no rock exposure, we encountered a low boss of fine-grained black mica-schist (1600); with siliceous veins running with the strike. Then we found some argillitic beds in which were some crumpled white sheets of apparently chalcedonic silica (1601).

After an outcrop of coarse quartzyte (1602) resembling somewhat the Thessalon quartzytes, but less granular, whose stratigraphic position we could not make out, on account of the interrupted nature of the exposures and the variation in the direction of the track, we noticed two dikes of more recent diabase (1603) cutting the slate conglomerate and running nearly coincident with the strike, and having a columnar structure about horizontal. Under the conglomerate here, *i. e.* just before reaching Cook's Mills, at the mouth of Serpent river, conspicuous outcrops appear of a fine mica schist (1604), which is probably the recurrence in force of the mica-schist before mentioned (1600). It is not bedded but massive, and becomes hornblendic, recalling some parts of the Vermilion series of Minnesota. This continues to Cook's Mills and forms the outcropping rock at the station and about the village. No positive observation was made on the stratigraphic relation of this hornblendic mica-schist to the slate conglomerate, but its place is assumed to be below the conglomerate because of the known relation of the Huronian (*i. e.* the described Huronian of Murray and Logan) to such rocks in other places.

SUMMARY OF THESE OBSERVATIONS.

It appears, therefore, that both northwest from Sudbury and eastward from Algoma there are two formations. The slate and the slate conglomerate in both sections constitute the upper formation. In the region northwest from Sudbury the underlying rocks are largely felsitic, but are also micaceous, and at the Stobie mines become hornblendic. These changes are identical with changes that are known to occur in the Keewatin in Minnesota. In the section eastward from Algoma the underlying formation seems to be the Missasaugui quartzyte with interbedding of green fissile schist, in part, and a mica schist varying to hornblendic schist, in part, the latter being further east.

There seems to be some irregularity in the order of succession in the section eastward from Algoma, bringing in several outcrops of strata that belong higher up in the series. If this be not illusory, and due rather to the winding of the railroad from north to south to avoid the hills, it may be accounted for by such faulting and upheaval as have been described in Minnesota, such as have produced the sudden, but indistinct, unconformities and transitions from the Huronian to the Keewatin, that have been described there. Further, the quartzyte which has been alluded to as the Missasaugui quartzyte, and supposed to be Logan's lowest gray quartzyte, is probably not his lowest gray quartzyte, but it is rather a constituent part of the Keewatin. It is allied in all its lithology no less than its persistent verticality to the Keewatin and seems to have been formed in the Keewatin ocean in the same manner as the jaspilyte beds of that horizon, *i. e.*, by chemical precipitation, the green schist layers showing such advent of basic eruptions or volcanic ash as could form chloritic schists in the same way as in northeastern Minnesota. The "lower gray quartzite," (No. 5 a), of the original Huronian, according to Logan's map of 1863, appears a few miles east of Thessalon at the lake shore, and there produces an unconformable contact on the gneiss of the Laurentian. This contact has been examined by Prof. Irving and more lately by Dr. A. C. Lawson, and they concur in the statement that the conglomerate is a pudding-stone of rounded masses, having a quartzyte matrix. There can be but little doubt that it is the same as that seen in the vicinity of Thessalon, and hence that it is the Thessalon quartzyte and *overlies* the slates and slate conglomerates, being near the top rather than near the bottom of the original Huronian. This mistake is apparently the same as made in eastern New York and in Vermont, where the granular quartz (?) and the Potsdam (or red sandrock) seems to overlap and hide from sight the formation immediately older, and lies in unconformity on a still older terrane—on the east on the gneiss of the Green mountains, and on the west on the gneiss of the Adirondacks. It caused the early geologists to question the existence of any such formation as the Taconic—that great series in which has been brought to light latterly a wonderful fauna of primordial life, and which extends from the Atlantic slopes to the western basis of the Rocky mountains. This overlap unconformity implies a sinking of the pre-existing land, and of the ocean's bed, bringing the later formed strata over the beach-limit that existed before.

We may conclude therefore that the observations that were made on the recent excursions confirm, at least do not contravene, the views lately set forth by Irving, Bonney and Lawson, and the conclusions published by the reports of the Minnesota survey, to the effect that the Huronian system, as now defined and understood by the Canadian geological reports, really embraces two or three formations; that one of these is the true Huronian, as at first described and mapped by Murray, another is the Keewatin of Dr. A. C. Lawson, containing the iron ores at Tower, Minnesota, and another is the series of crystalline schists which we have styled Vermilion series. In other places these three formations have been fully treated.* They are distinctly separated by lithology and unconformities that have been noted from Vermont to Minnesota, and

[NOTE.—At Algoma are occasional very interesting boulders (1605). They contain large (and small) rounded, whitish-green feldspathic spots which are distributed somewhat like porphyritic crystals, but they have not the angular periphery of crystals. They are in a matrix of ordinary diabase of dark green color, and the spots make the rock noticeable, their largest sizes being somewhat larger than an inch in diameter. Some of these boulders are put in the foundation wall of the great hotel which the Canadian Pacific railroad projected at Algoma, and that is where we saw them first. Mr. Selwyn recalled the dike cutting the Animike on the high ridge back of Silver Islet, as the only spot known where such rock is in place. This dike was visited in 1879 by the writer and his samples are numbered 601 (Tenth annual report, p. 56), but the crystals in the dike are distinctly angular and not noticeably greenish. These boulders are suggestive of the existence of such source in the country toward the north from Algoma.

Another common boulder at Algoma is constituted of quartz-pebble conglomerate, the pebbles in which are of that ambiguous character seen in the Missasaugui quartzyte—whether fragmental or of chemical precipitation. While the boulders themselves are referable to the Thessalon quartzyte, high up in the Huronian, the pebbles that compose so large a portion (1606) are referable to that unconformably underlying vertical quartzyte (the Missasaugui quartzyte) seen, as above described, a few miles east of Algoma.]

* See the Seventeenth Annual Report, Minnesota survey.

should no longer be included under a single term—at least not under the term Huronian, which at first had a correct and adequate definition embracing but one of them.

VI.

Additional Rock Samples Numbered.

[Collected by N. H. Winchell, intended to illustrate his field notes in 1888 and 1889.]

1501. Vein rock and pyrites, from the quartz vein supposed to be auriferous, at Eagle Nest lake, east of Vermilion lake; according to Robert Angst this also contains metallic copper. [See description of this vein in the 15th annual report, p. 32.]

1502. Chemical silica, Tower, embraced in considerable masses in immediate proximity to the chalcedonic, in the green schist.

1503. Chemical (granular?) silica, in a vein about half an inch wide running transverse to the green schist, Tower.

1504. Chalcedonic silica, immediately adjacent to 1503; reddish, in thin laminations.

1505. Some of the schist seen interstratified in argillitic slate at the low "slate" knoll south of the "south ridge" and west of Tower.

1506. Four samples showing the relations of the chemical silica to the hematite, at the Lee mine, near Tower.

1507. Brecciated jaspilyte, cemented by a finer breccia of the same. From a boulder, but fairly illustrating the beds in situ.

1508. Black schist with pyrite balls, at the pits at the N.W. base of Chester peak.

1509. On the top of Chester peak some small veins consist of chalcedonic silica, crossing the jaspilyte banding.

1510. At Ely; a sample of the green schist showing the forms of two boulders, and the darker green rock separating them.

1511. Amygdaloidal portions of some of the boulders, showing the tubes perpendicular to the surface; from the green agglomerate at Ely, at the railroad cut.

1512. Chalcedonic silica from veins and spots in the rock 1510.

1513. Vein matter in 1510, similar to 1501. Probably auriferous.

1514. Sample of the gneiss at the Hinsdale quarry, *i. e.*, in the Giant's range.

1515. Frazer's quarry, North Redwood P. O., near Redwood Falls, on the Minnesota river. Massive, gray, uniform gneiss, without bands of color.

1516. Same place. Gray gneiss, with alternating and inter-shading micaceous and feldspathic belts.

1517. Same place; samples showing much red orthoclase.

1518. Gneiss, with much red orthoclase. Morton quarries, near Redwood Falls.

1519. Gneiss, showing inclusion of a micaceous, "black rock." Morton quarries.

1520. From a granite mound on sec. 12, T. 111—38. Redwood county. A bedded granitic rock, showing no red orthoclase.

1521. The gray quartzyte at Pokegama falls on the Mississippi river near Grand Rapids. Compare 257 (H)—259 (H).

1522. The gneiss at the upper falls of Prairie river.

1523. Showing micaceous schist in alternations with the gneiss at the upper falls of Prairie river.

1524. Coarsely crystalline orthoclastic belts, from the gneiss at the upper falls of Prairie river.

1525. Reddish and chloritic mass wedged in the gneiss at the upper falls of Prairie river.

1525 (a). Spottedness shown on the quartzyte at Prairie river.

1526. Shows another spottedness. Here the rusty spots weather out and produce a pitted surface on the quartzyte; same place.

1527. Hematite and impure hematite, siliceous and jaspery. Prairie river falls.

1528. Rock shown at about the horizon of this hematite.

1529. Somewhat above 1528. Finely laminated or "streamed," also brecciated, jaspilyte, with some vitreous silica.

1530. Jaspilyte and hematite, closely intermixed, but not inter-laminated. The red jaspilyte appears as a felsyte.

1531. Hematite at this horizon; about one-fourth is hematite.

1532. Some of the quartzite that underlies this ore is conglom-eritic in patches.

1533. Red shale. Griffin's camp, N. E. ¼ Sec. 22, 56-24.

1534. Iron-bearing rock. The ore impure and in broken and irregular sheets; hematite.

1535. Same as 1534. Pit No. 2, but struck at 15 feet below the surface.

1536. Same as 1534. Pit No. 3. Struck at one foot below the surface.

1537. Slaty hematite, rather low grade (47 p. c. iron) N. W. ¼ N.W. ¼ Sec. 21, 56-14.

1538. Magnetic iron ore, Sec. 23, 60-23. Fleck's location; from John Beckfelt.

1539. Rock associated with 1538.

1540. Duluth; on the Weller road, about 1½ miles from lake Superior, but about 2 miles from the business part of Duluth. Gray, porphyritic gabbro, with a fine magma.

1541. Shows contact of the "red rock" on the gray rock 1540.

1542. Red rock, crystalline. with some light-green spots, from the Weller road, same place as 1540.

1543. Granular silica, appearing somewhat as if originally chalcedonic (see 519). Same place.

1544. Vein matter in gabbro, at Rice's point.

1545. Serpentinous vein matter in gabbro at Rice's point.

1546. Quartz crystals lining vugs in dense hematite. Lee mine, near Tower.

1547. Reddish, earthy-looking jaspilyte. Lee mine.

1548. Breccia of fine pieces of hematite, red jasper and quartz, somewhat stratiform. Lee mine.

1549. Tarnished hematite, appearing as if it might be some copper sulphide; Lee mine. Coatings; Lee mine.

1550. Finely banded (sedimentary?), whitish jaspilyte; Lee mine.

1551. Hard hematite, with included crystals of chalcopyrite.

1552. Piece of chalcedonic quartz mass, embraced in a boulder of Stuntz island conglomerate (agglomerate), near the Lee mine.

1553. Piece of gray quartzose pebble or gray "felsyte," contained in the same boulder as 1552.

1554. Pebble from the same boulder containing vitreous quartz.

1555. Matrix of this boulder containing the above pebbles.

1556. No. 1553 becomes porphyritic in 1556.

1557. Light colored graywacke, or novaculyte, greenish white, with distinct grains of glassy quartz: at the railroad just south of Tower pit (Nos. 8 and 9). Dips N. about 75°—80°.

1558. Green schist, south of the Stone mine, at the railroad cut.

1559. Interbedded jaspilyte in 1558.

1560. Fine grains of disintegrated white jaspilyte; dump of the Stone mine.

1561. Breccia of jaspilyte and of hematite cemented by chemical silica; dump of the Stone mine.

1562. In the dump of the Stone mine some of the quartz crystals are superficially roughened and corroded—some of the fine crystals. What caused it?

1563. Green shale breccia; from the dump at the scram southwest of the Breitung mine.

1564. Botryoidal limonite on quartz crystals and on hematite; same place.

1565. Flinty, gray to dark gray jaspilyte, from the dump of the hoisting-shaft of the same place. Compare 866 B. and 1277.

1566. Rotted, angular masses of jaspilyte as intersected by the water-bearing course of a joint crossing a mass of contorted jaspilyte, at the Breitung mine.

1567. Pebbly conglomerate, embracing small grains of vitreous quartz; a patch or belt in otherwise typical jaspilyte. In the ridge that remains separating the Breitung from the Tower mine.

1568. A jaspilyte egg, somewhat concretionary, at least indistinctly concentric in some color bands. From the cut made for the high tunnel running south from the Tower pit (No. 9), where it crosses the light "ore streak."

1569. Coarse graywacke, rather soft, taken from the roof of the same tunnel, crossed by some thin veins of chalcedonic silica, about 15 feet from the southern entrance.

1570. From the dump, Breitung mine. What is the fine red mineral in crystals?

1571. Siliceous "green schist" interbedded in jaspilyte north of the Tower mine.

1572. From the jasper at the east end of the Stuntz mine. What is the white cementing vein-mineral? It appears to be granular silica, but also shows apparently cleavage surfaces.

1573. Gray gneiss, the rock at North Bay, on lake Nipissing, Ontario, in general, after the weathered surface is removed.

1574. Reddish-weathered gneiss, a surface condition of the rock at North Bay, Canada.

1575. Micaceo-hornblendic, garnetiferous rock embraced in No. 1573, as foreign masses, some of them fifteen feet across.

1576. Hydro-micaceous schist, silky-sericitic, from the "Huronian" at Wahnapitae, Ontario.

1577. The rock that contains the nickel ore at the Stobie mines, near Sudbury, Ontario, a gray quartzyte resembling the Pewabic quartzyte of Minnesota. Compare 1322 and 1340.

1578. The ore from the Stobie mines, Ontario.

1579. The "hornblendic rock" from the dump of the deep shaft which was abandoned at the Stobie mine, Ontario.

1580. Orthoclase found in veins in 1579.

1581. The dioryte dike which is supposed to cut the country rock at the Copper Cliff mine, Ontario. With this the ore is in some way associated.

1582. Ore of the Copper Cliff mine.

1583. Red felsyte, adjoining 1581 on the north.

1584. The conditions of the mined rock and the sulphides at Copper Cliff mine, Ontario.

1585. Matrix of a coarse conglomerate with boulders of red-weathering felsyte, one-quarter of a mile east of the Copper Cliff mine, north of the railroad.

1586. Porphyritic rock, the disseminated crystals being of hornblende and coarse. At the railroad cut, a mile and a half from Sudbury, toward Ohnaping.

1587. Dike-rock, cut by the grade, near the same place.

1588. Somewhat granitic felsyte, enclosing masses of dark basic rock in a manner like those at North Bay; reddish weathering; a quarter of a mile further toward Ohnaping.

1589. Ore of the Murray mine, Ontario.

1590. Black slate, Vermilion river, at the railroad crossing.

1591. Calcareous "concretions" in the black slate at Vermilion river. Same place.

1592. Slate conglomerate, N.W. from Vermilion river; from a ridge that rises perhaps 150 feet above the railroad.

1593. A mile and a quarter east of Algoma, on the north shore of lake Huron. Green slate, dipping S. 10°, W. 45°-65°.

1594. A mile and a half east of Algoma. Roofing slate, gray to black.

1595. Slate conglomerate, 3d of Logan's map. Underlying 1594.

1596. Soft argillyte, with lenticular spots and laminations of chalcedonic silica, next east of the slate conglomerate of 1595.

1597. Supposed chalcedonic silica, from 1596.

1598. Fine grained quartzyte, about 4 miles east of Algoma.

1599. From the great "slate conglomerate" east of Algoma, at a point east of the last.

1600. Fine-grained, nearly black, mica schist; at a mile and a half east of the last.

1601. Crumpled, white, apparently chalcedonic silica, from some argillitic beds east of 1600.

1602. Coarser quartzyte, still farther east.

1603. Dike-rock, cutting conglomerate.

1604. Hornblendic schist, Cooks Mill, at mouth of Serpent river.

1605. Diabasic boulders, with coarse feldspar crystals. Found at Algoma (compare 601).

1606. Quartz-pebble conglomerate boulders. Algoma Mills.

VII.

AMERICAN OPINION ON THE OLDER ROCKS.

CONTENTS.

With incidental citations from Chester Dewey, W. W. Mather, L. Vanuxem, James H. Safford, William B. Rogers, Alexander Murray, J. J. Bigsby, J. Barrande, A. R. Selwyn, J. B. Marcou, Robert Bell, L. W. Bailey, Thomas Macfarlane, J. W. Dawson, C. T. Jackson, J. W. Foster, M. E. Wadsworth, C. R. VanHise, T. C. Chamberlin, James D. Dana, Charles D. Walcott, and others.

By ALEXANDER WINCHELL, LL.D., F.G.S.A.

INTRODUCTION.

As preliminary to a careful inquiry into the nature, arrangement and geological history of the older rocks of North America, I desire to collate the views which have been recorded by competent geologists during the last half century. Such a synopsis of opinions which have marked the progress of our science and have brought it through many labors, conjectures, errors and successes, to the very creditable position which American geological science holds at the present day, will greatly facilitate the work which remains to be done, by placing within convenient reach, the chief data of such progress, with copious references to the documents from which the information is drawn. Such a compendium of historic data will prove especially useful to geologists who have not the leisure to look up and digest the original documents. Since however, compilations of opinion, though offering opportunities for condensation, and even improved lucidity of statement, must necessarily lie under the suspicion that the author's view has been presented with incompleteness or with unintended coloring, the writer has deemed it best to present opinions generally in the exact language of their authors.

The present attempt bears some resemblance to that of Messrs. Whitney and Wadsworth in "Azoic system"*; but it will readily be seen to have a different aim, and to produce results far from identical. Their controlling purpose was, to prove, from citations, that during the time which has elapsed since the "Azoic System" was proposed by Foster and Whitney, no facts have been reported rendering it necessary to conclude that the "Azoic System" as conceived by them, is not both azoic and indivisible. My purpose involves an examination of such a position, but it involves much more. I propose to adduce the facts without the influence of an unalterable predetermination. I propose to select them impartially—rather in the interest of the writers than in the interest of any theory. I propose to give them an unbiased interpretation or to leave them without comment, to be interpreted by the reader. Beyond all this, it is proposed to cite many opinions not bearing on questions of taxonomy and nomenclature—opinions on all subjects whose agitation has taken part in the progress whose fruits we en-

*J. D. Whitney and M. E. Wadsworth, *The Azoic System and its proposed subdivisions*, Bulletin of the Museum of Comparative Zoology, Geological Series, Vol. I, pp. xvi and 331-565.

joy—problems of structure, superposition, metamorphism and geognostic evolution in general.

The method of Whitney and Wadsworth is geographical; mine may be denominated personal; neither traces consecutively the evolution of an idea or concept. Concrete methods have peculiar uses; and it is hoped the method here pursued may be useful as complementary to theirs, even if its subject matter possesses fewer advantages than I anticipate.

In some of these respects the method of the following sketch resembles that of Dr. Hunt in his Historical Introduction to the Azoic Rocks*. It differs, however, in the important feature of giving the views of investigators in their own language. One does not feel certain, in reading the memoir of Dr. Hunt, that he gets exactly the meaning of the original statement. In some cases, it is certain, the meaning is inadvertently colored, or even reversed. Dr. Hunt's treatment also, seems to the writer, deficient in method. It lacks consecutiveness; it abounds in repetitions; the connection of parts is more verbal than logical. The order would seem rather to be that of association of ideas in the author's mind than one determined by the logical or historical relation of topics. For such reasons, it is difficult to follow and comprehend. However this may appear to others, it seems certain that comprehension and clearness of conception must be facilitated by following the growth of conviction in each investigator's mind separately—introducing the biographical element into the history of geological ideas.

In the history of this advance, it has been the fortune of some to observe nature in the field, of others, in the laboratory, of still others, to collate records in the library—and I need hardly remind the reader that the efforts of many others have been expended in provinces not entered in the present discussion. Those who have worked in the field have supplied the greatest volume of records suitable for use in the compilation which follows.

In attaining the status which has been achieved, there must have been many false steps taken—erroneous observations, false interpretations, hasty generalizations, untenable suggestions, ill grounded theories, all mingled from time to time, with the influence of the "personal equation." Still, it is safe to assume that every investigator has been actuated by a controlling love of truth, and has done perhaps, as well as any other investigator would have done in precisely the same circumstances. If any have lost patience with

*Report E, Second Geological of Survey Pennsylvania.

a fellow-worker, it is profitless to reproduce the sarcasm in which impatience has found relief. The language of scorn or contempt has contributed nothing to the noble progress which we contemplate.

As intimated, the present summary of opinion sustains a special relation to the contemplated sequel of the present memoir. Whatever its separate value may be, its use to the writer consists in the light which it sheds on an investigation to a large extent original. Circumstances have turned the writer's attention, during a few years past, toward the study of the older rocks. Though from boyhood familiar with the forms and aspects of the crystalline and sub-crystalline masses of Dutchess, Litchfield and Berkshire counties; though officially connected with public surveys over the crystalline expanses of Michigan; though long since a student of similar rocks in Missouri, Massachusetts and Maryland, it is true that the present research has been in a field comparatively new, and conducted by methods in part unknown to the older investigators, and but imperfectly mastered by most of us. It has seemed to the writer that one of the fields in which he has studied presents the problem of the older rocks under simplifications which promise advantages not enjoyed by the older students of terranes of high relative antiquity. Perhaps he deceives himself in thinking these advantages have brought him—a comparative novice—into possession of glimpses of truth which have been hidden from abler, but less fortunate students. He hopes howêver, the result will justify his confidence.

EBENEZER EMMONS.

1824. Ebenezer Emmons, in 1824 a pupil of Dr. C. Dewey, was associated with the latter in the preparation of a geological description and map of Berkshire county, Massachusetts, and of a small part of the adjoining states.* In this description the rocks are arranged in the following order (the whole being here inverted):

3. Transition limestone, &c.
2. Quartz, Primitive limestone, Primitive argillite (Upper Primary).
1. Granite, Gneiss, Talcose slate, Mica slate (Primary).

The second division indicates the elimination of the "Taconic idea" eighteen years before it received a formal designation.**

*_American Journal of Science and Arts_, Vol. 8, 1824, pp. 1, 240. An abridgement of this was included in "A History of Berkshire County," in 1829.

**1819. In a "_Sketch of the Mineralogy and Geology of the vicinity of Williams College_" (_Amer. Jour. Sci._, Vol. i, p. 327, ii, 246, 1820.) Dr. Dewey had already published the germinal conception of the above arrangement, and of the Taconic system. The rocks and minerals were arranged in the following order: 1. Granite. 2. Gneiss and Mica

1837. At the end of the first season's observations within the Second Geological District of New York, professor Emmons described the rocks, in the nomenclature of the day, as Primitive, Transition and Tertiary.* Under the first, he describes first, Granite, which is "not strictly speaking, granite; that is, it is not composed of quartz, feldspar and mica; neither is it a true sienite, for even the hornblende disappears almost entirely for miles. It is mostly feldspar. . . . It contains the beautiful Labrador feldspar . . . often in large masses. . . . The color of the rock is usually grey, greenish or bluish. . . . It rarely contains quartz. . . . In Essex county it forms mountain masses. . . . The other primitive rocks of the northern counties are gneiss, hornblende and granular limestone. The talcose and mica slates rarely occur." The following is the succession reported, arranged here in descending order:

TERTIARY, consisting of grey sand and marly clay, with shells of recent aspect.

TRANSITION ROCKS. 1. Calciferous sandrock, including Potsdam sandstone. 2. Transition or blue limestone.

PRIMITIVE. Granite, Gneiss, &c.

1838. Professor Emmons again ranges the rocks of St. Lawrence county as Primitive, Transition and Tertiary†. The Primitive region he also designates "the gneiss district," but he states that "the rock is not purely gneiss," but only "the predominant rock," the region embracing also "granite, limestone, sienite, hornblende, steatite, serpentine, &c." The granite, he says, "occurs in beds and veins subordinate to the gneiss; . . . in huge angular beds or protruded masses; in the form of veins branching irregularly into the adjacent rock, and in overlying masses analogous to overflowing lava currents or greenstone." He speaks of it as sometimes "interlaminated with gneiss or other rock," but considers such position "accidental" (p. 196). The granite and gneiss contain in places, more or less carbonate of lime, or of lime and magnesia. The "primitive limestones" he speaks of as interstratified, but is particular to discriminate them from the marbles of Vermont and Massachusetts, "especially those of Berkshire county."‡ He gives eleven diagrams to illustrate the position that

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slate. 3. Quartz. 4. Granular limestone. 5. Argillaceous slate. It will be noted that there is one limestone formation. These views were adopted by Prof. Amos Eaton in his "Index to the Geology of the United States," 1820, though later, he became an indefatigable original observer. (*Amer. Jour. Sci.*, xiv, 147, 1828.)

**First Annual Report*, New York, 1837, Assembly, No. 16, pp. 109-117.

†*Second Annual Report*, New York, 1838, Assembly No. 200, pp. 194-217.

‡This is further insisted on, p. 232.

we have the same evidence of the igneous origin of the primitive limestone as of the igneous origin of granite—that is, it occurs interbedded, penetrating and ramifying in relation to the granite.*

The sandstone at Potsdam is said to rest directly on the primitive rock, but it is no longer identified with the "Calciferous sand rock" of Eaton, (p. 214). On page 217, it is called for the first time, "the Potsdam sandstone" (pp. 217, 230.)

Treating of Essex county he speaks of the granite as "composed essentially of Labrador feldspar and hypersthene," and decides to style it "Hypersthene rock" (p. 220). It contains extensive beds of iron ore, sometimes branching and vein-like. The primary limestone "uniformly occurs in veins" in the hypersthene rock. The gneiss of the country is limited in extent, is interlaminated with saccharoidal limestone, and contains beds of magnetite and hæmatite (p. 221).†

We have no documentary evidence of the progress of the evolution in Dr. Emmons' mind previously to the publication of the Gazetteer next to be mentioned. But professor Dana has recorded the fact ‡ that, according to information from professor James Hall, a discussion of "Taconic ideas" took place at the meeting of the "Association of American Geologists and Naturalists" at Philadelphia, in April, 1841. In this, Dr. Emmons was opposed by H. D. Rogers, E. Hitchcock, W. W. Mather and James Hall, while Lardner Vanuxem favored his views.‖

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*Numerous other reputable geologists have entertained the same rather remarkable opinion—von Leonhard, Giudini and Rozet.

†The Tertiary beds are of some considerable extent, occupying "not only the Champlain valley but that of the St. Lawrence and Hudson also." He notes it as a "marine formation," and states that "above these clays, &c, we have the modern group composed of boulders, pebbles and sands" (238). Emmons here bestows the names "Mt. Marcy" and "Adirondack group" or "Adirondacks"—the latter to embrace the high summits of northern New York. (pp. 242, 243).

‡*Amer. Jour. Sci.* III., xxxvi, 412.

‖The Proceedings of this Meeting are found in the "*Trans. Assoc. Amer. Geologists and Naturalists*, 1840-42. but this discussion not having been reported, no mention of it appears, under a rule of the Association. The proceedings are reported also, in *Amer. Jour. Sci.*, xli, 158, 1841. The grounds of Vanuxem's defence are stated in *Report on the Third District*, 1842, pp. 22-23. He styles it "The Taconic or Intermediate System," and says, "the Cambrian System holds the same position." Mather's reasons for regarding the Taconic rocks as a metamorphic condition of the Champlain rocks are given (p. 438) at the close of a chapter on the Taconic system; also p. 464 (*Report Third District of New York*, 1843, pp. 422-438), Professor Hall in his report on the Fourth District, embraces the Taconic system in his enumeration, and nowhere expresses any dissent.

"The comparison of views at the meeting", says professor J. D. Dana, (*Amer. Jour. Sci.*, III., XXXVI. 413, Dec., 1888) "resulted in inducing Prof. Rogers and Prof. Hall to take the field for the study of sections over the Taconic region. The season had just passed when Prof. Rogers made a report on his results to the American Philosophical Society at Philadelphia (*Proc. Amer. Phil. Soc.*, Jan., 1842) sustaining the views which Hitchcock, Hall, Mather and himself had before favored".

1841. A communication appeared from Dr. Emmons on "The Geology of Montmorenci,"* which, according to Dr. Selwyn, "seems to be of considerable interest and importance, in view of recent discussions." It supplies some of the evidence on which Dr. Emmons determined the existence of a great fault, reaching from the St. Lawrence into Vermont and New York. On the highway from Quebec to the falls, at the Beauport river, a regularly bedded, horizontal, nearly black limestone outcrops, "presenting a remarkable contrast with the highly inclined rocks of Quebec." A "black slate," also, "apparently rests against" the limestone. A fault or uplift is thought indicated by the facts here observed," along the line which the road passes." The first outcrop is" very clearly Trenton limestone," and "the slate is the Hudson River slate."

At the fall, the bed of the river above, is gneiss. Reposing horizontally on its edges, is, first, the Potsdam sandstone, stained with copper, and not over ten feet thick; second, coarse bowlders, as at Chazy, N. Y., considered the upper portion of the Potsdam; third, "a compact limestone" conformably overlying, containing encrinites. This "graduates into a gray, crystalline limestone," with broken encrinites. Succeeding this is the Trenton, 60 or 70 feet thick. The absence of the Calciferous and Chazy is noted; though this is not considered remarkable.

Below the fall, the rock forming the fall is seen to be fine-grained gneiss. Against this, the Black slate of the Hudson river reposes, but with an unconformable inclination. Dr. Emmons recognizes here a fault, with an uplift on one side "and a down heave on the other, by which the slate has been thrown into an inclined position."

This fault is regarded as extending south along the Beauport road, and even into the state of Vermont; and "may be particularly traced on a line connecting Johnson's mountain in Lower Canada, several points on the Missisque bay adjacent to the Provincial line, and also, at the remarkable uplift at Snake mountain, in Addison, Vt. A line uniting those points and several others in the same direction, marks the line of a great disturbance which has deranged the lower Transition rocks for at least four hundred miles."

In view of these facts, Dr. Emmons asks; "May not the great fault have caused the confusion in the writers on geology, in re-

*The *American Magazine*, November, 1841. See this reproduced in *American Geologist*, ii, pp. 94-100, August, 1888. The date of this paper was wrongly printed in the *American Geologist* at first, but was corrected afterward (vol. iv, p. 387).

gard to the lower Transition rock, particularly the Hudson River slates and shales? May not the same derangement exist in England and Wales, and have been the cause, at least in part, of their separation from the Silurian system, and of their being considered as one distinct therefrom, and which has been called the Cambrian System?"

He speaks of the horizontal position of the Hudson River rocks at Pulaski, Lorraine, Rodman and Pinckney, in New York, conformable with the Silurian system; and of their inclined position in Rensselær and Washington counties, in Vermont, and the entire length of Lower Canada. In the latter region, they agree with the Cambrian (omitting the lower portion.) He speaks of this as a conviction of long standing.

He continues: "It is proper to notice here one source of difficulty in regard to the rocks of the Hudson river, especially on their eastern border. It is the fact of their overlapping in this direction, the Trenton limestone and the other Transition rocks beneath. The consequence has been that, in traveling from east to west, or from Massachusetts and Vermont to New York, we pass directly from the Primary mass to the higher members of the Transition system; consequently they [geologists] have placed them upon the Primary, and considered them as the lowest of the Transition; whereas there intervenes between the Hudson river slates and the Primary, the Trenton limestone, the Birdseye, Calciferous, and Potsdam sandstone, the aggregate thickness of which exceeds a thousand feet. Not one of the lowest members of the Transition system appears in the eastern prolongation, between the Highlands of the Hudson and the Highlands north of Quebec, adjacent to the Primary, in consequence, as has already been said, of the overlapping of those rocks formerly termed Greywacke, or now known as the Hudson river series, to the talcose slates of the Primary, and also, the great correspondence in kind and amount of their dip."

Speaking of the tenuity of the Hudson River rocks where found horizontal, and their great thickness where inclined—amounting to 20 or 25 miles—he says:—"There can be no doubt that east of the Hudson, there are numerous repetitions of the same layers; for it cannot be supposed for one moment, that any of the formations above the Primary, can be of this enormous thickness which observation seems to indicate."

1842. While occupied in the preparation of his final report on the Second District of New York, Dr. Emmons drew up an article on the "Topography, Geology and Mineral Resources of the State of New York", which was published in March, 1842.* In this article he says: "The rocks (upon the eastern border of New York, adjacent to Vermont, Massachusetts and Connecticut) are situated between the gneiss of Hoosick mountain on the east and the slates of the Transition on the west. They occupy, therefore, geographically, as well as geologically, an intermediate position–the rocks on the one hand bearing a very close resemblance to the Primary on the east, and on the other, a great similarity to the Transition slates on the west. Still, as a whole, the rocks of the Taghkanic range may generally be distinguished from those on either side, their general character being derived from the presence of a large proportion of magnesia, which imparts to the rocks a softer feel and a peculiar greenish color. It is not proposed in this plan, to separate these rocks from the Primary, but to consider them as belonging to the upper portion, and to speak of them as the Taghkanic rocks, or perhaps as the *Taghkanic System*. . . Considering them for the present, as belonging to the upper portion of the Primary, the Taghkanic rocks will be composed first of a peculiar talcose slate, or a magnesian slate in part; in other parts, it is plumbaginous, which strongly soils the fingers. . . Second, of white, gray and clouded limestone, varying in texture from fine to coarse-granular, often interlaminated with slate, the latter often merely coloring the limestone, so as to impart that clouded appearance . . . Third, of granular quartz, or a sandstone generally silicious and of a brown color . . . The whole *Taghkanic System* is clearly stratified, and is wholly unconnected with gneiss, serpentine, granite, sienite, steatite or hornblende . . . "

This distinct announcement of the Taconic System, it will be observed, appears in a volume printed in March, 1842. It must have been drawn up, probably, some months previously. Professor J. D. Dana, by a slip extraordinary for him, has quoted a passage from Mather's Fifth Annual Report†, the meaning of which is that the writer, on January 20, 1841, (Dana says Febuary 1, 1841), regarded the "granular quartz" (embraced in the Taconic) as simply "the Potsdam sandstone in a metamorphic state", and the associated "granular limestones" as belonging to the same geological epoch", and that "the rocks generally along the eastern border of New York, and probably all the rocks from the New York State line east to the Connecticut valley are similar". But these, it appears, were not Emmons' views on the first of February, 1841. The

**A Gazetteer of the State of New York*, etc., Albany, 1842. J. Disturnell, March, 1842, p. Attention has been called to this and other early literature bearing on the Taconic system, by Lieut. A. W. Vogdes, in the *American Geologist*, vol. II, 1888, pp. 352-55.

†*Amer. Jour. Sci.*, III, XXXVI, 411, beginning, "The granular quartz of Bennington", &c.

conception of the Taconic system was not originated in the brief period between this date and January 1, 1842—the date of Emmons' final report. The citations already made from the geology and map of Berkshire county show that the body of rocks between the Primary granites, gneisses and schists, and the Transition rocks above, had been isolated eighteen years before, though at that time designated "Upper Primary". If Emmons made no mention of them in his annual reports, it was because they were not embraced in his district. In a final report, however, he tells us he felt constrained to carry into effect a plan formed in the beginning of the survey, "to furnish the materials necessary for a complete work on the New York rocks" and to make "this volume distinct from, and independent of, the reports of the other districts"* In another connection he informs us that the conception of the Taconic dates from 1838.* *

In his Final Report on the geology of the Second District,† Dr. Emmons gave the following classification of the Primary rocks:

I. UNSTRATIFIED.	II. STRATIFIED.	III. SUBORDINATE.
1. Granite	1. Gneiss.	1. Porphyry.
2. Hypersthene rock.	2. Hornblende.	2. Trap.
3. Primitive limestone.	3. Sienite.	3. Magnetic, and
4. Serpentine.	4. Talc or Steatite.	4. Specular oxide of iron.
5. Rensselærite.		

The granites are recognized as erupted at different epochs. The hypersthene rock contains disseminated grains and extensive beds of magnetite (p. 222). The primitive limestone is still regarded as unstratified and igneous in origin (pp. 38, 225). Adverse opinions are examined, and new evidences adduced. Serpentine is also alleged to be never stratified, and to have been erupted, probably, at different epochs (pp. 69, 70). Yet it never occurs in dikes or veins, and causes no alteration in contiguous rocks. The same opinions are entertained of Rensselærite (p. 74). "The term sienite is applied to a stratified rock composed of feldspar and hornblende" (p. 80). The magnetic and specular oxides of iron are regarded as of igneous origin (p. 97). Of the origin of the stratified primary rocks nothing is here recorded.

The seventh chapter of this volume (pp. 135–164), is devoted to the "Taconic System," though none of the rocks have been observed to occur in the Second District of New York. "A large portion of its rocks or masses are interlocked between the New England or primary ranges upon the east, the most important of which

Report, Second Dist., 1842, p. 135.

***American Geology*, Pt. II, pp. 5 and 6.

†*Geology of New York*, Part II, 1842, p. 23. This was published May 26, 1843.

is the Hoosick mountain, and the Taconic (range), with the more westerly abrupt hills, upon the west—or the eastern border of the New York Transition system." On each side, the rocks partially blend with the contiguous systems. The lower limit of the Taconic system is the upper limit of the Primary. The statement that "these rocks belong to the earliest deposits" (p. 141) would imply that gneiss (of the Primary) is not regarded as sedimentary in origin*. The upper limit of the Taconic system is the Potsdam sandstone—which at this epoch was regarded as the base of the fossiliferous series, or at least of the Silurian series.

The formations here embraced in the Taconic system are the following, in descending order:

5. Stockbridge limestone, coarse granular and of various colors.
4. Granular Quartz rock, generally fine grained and brown, but sometimes white, granular and friable.
3. Magnesian slate having a soft feel. Principal mass of Taconic mountains (p. 153). Perhaps repeated in Greylock mountain, on the east of the Sparry limestone.
2. Sparry limestone.
1. Taconic slate, at the western base of the Taconic range, adjacent to the Hudson River shales.

The order of superposition, however, is not regarded as settled (p. 150).†

This is what Dana calls Phase I.

It is difficult to appreciate the reasons given by Dr. Emmons for placing his Taconic slate at the bottom (supposing this is what he means)—even in the light of his own section from Adams, Massachusetts, westward to the Champlain rocks of New York (given on p. 145). It is true the beds have a general dip eastward, giving the "Taconic slate" the appearance of dipping under all the other members; but the "Taconic slate" lies contiguous to the Champlain rocks, and even extends under them, though apparently by an overslip of the latter.

It is a singular inconsistency of Dr. Emmons, that in explaining the distinctions of the four limestones from the Primary to the Champlain, he expressly ranges the "Sparry limestone" above the "Stockbridge limestone" (p. 142)—an order which he was destined later to accept for the whole Taconic series. Similarly, (p.

*"Dividing the rocks into two classes, the primary and sedimentary" (p. 290) he says, elsewhere. See also p. 416.

†There are some indications that the order intended by Emmons is the reverse of this. So Mr. Marcou has understood him, in "The Taconic system and its position in stratigraphic geology" (*Proc. Amer. Acad.*, xii, 174-256, 1885.)

142) he places the "magnesian slates" below the "fine aluminous slate ("Taconic slate,") an order which he immediately, but with apparent unconsciousness, reverses (p. 144) and, though somewhat hesitatingly, defends (p. 147).

The Stockbridge limestone must be distinguished from the Primary limestone below, and the Sparry limestone must not be confounded with a silicious limestone occurring in the "Champlain group" above. Similarly, "the "Magnesian slate" must be distinguished from the lower Talcose slate of the Primary, and the Taconic slate must not be confounded with the shales and slates of the Hudson river. The Taconic rocks are entirely destitute of fossils ; but "they furnish us with a knowledge of that state which immediately preceded the existence of organic beings" (p. 164). They are regarded as "equivalent to the Lower Cambrian of Professor Sedgwick," "the upper portion being the lower part of the Silurian system."

In the "Tabular Views" of the sedimentary rocks of New York (p. 429), the members of the Taconic system are given as follows:

4. Granular Quartz [=Potsdam sandstone.]
3. Stockbridge Limestone [=Blue limestone of Hudson Valley.]
2. Magnesian Slate [=Slates of the lowest formation of the Appalachian System.]
1. Taconic Slate.

I have placed at the right in brackets the equivalences of the Taconic members as maintained by professor H. D. Rogers, in 1844.*

It will be noticed that the relative positions of the Granular Quartz and Stockbridge limestone here are the reverse of those given near the commencement of this report. Also, the Sparry limestone is omitted.

1844. Dr. Emmons issued a thin quarto volume entitled "Taconic System," and dated December 2, 1844, containing the results of the previous two years of study. The Taconic system appears with important changes and an extension of area. The contents of the memoir were exactly reproduced (except the Preface) in his Report on the Agriculture of New York.†

1846. In the first volume of his Report on the Agriculture of New York,‡ he devotes the fifth chapter (68 pages) to a fresh dis-

* In May, 1844, Prof. H. D. Rogers returned to a discussion of the Taconic system, in his presidential address before the Association of American Geologists and Naturalists at Washington (*Amer. Jour. Sci.*, xlvii, 137, 247, 444). He seems to have been the first to suggest that the Potsdam sandstone might not be the absolute base of fossilization among Amer can rocks.

†*The Taconic System, based on observations in New York, Massachusetts, Maine, Vermont and Rhode Island.*

‡*Agriculture of New York*, vol. 1, 1746. p. 55.

cussion of the Taconic system. Stimulated by the opinion of the brothers Rogers, accepted by Mather, E. Hitchcock and Dr. Samuel L. Dana, that the Taconic rocks were merely metamorphic conditions of the lower members of the New York or Appalachian system, he resumes, with new facts, a presentation of evidences sustaining his former positions, 1st, that the Taconic rocks are "inferior to the Champlain division of the New York system, or the lower division of the Silurian system of Murchison (p. 55); 2d, That they are a series of sediments reposing directly on the Primary system; 3d, That they contain previously unknown organic remains; 4th, That the lithologic members of the Taconic system have a different order of arrangement from that found within the New York system, and are much thicker than those to which they have been supposed equivalent in that system. The members of the system, as now recognized, are as follows:

6. Black slate (hitherto included in Taconic slate), with *Atops trilineatus* and *Elliptocephalus asaphoides.* I.

5. Taconic slate (with seven subdivisions), including Hoosick roofing slates with *Bucoides* and *Nereites.* III.

4. Sparry limestone (of Eaton). II.

3. Magnesian slate of Taconic and Saddle mountains.

2. Stockbridge limestone, in the Hoosick and Housatonic valleys, and extending to Sing Sing.

1. Brown sandstone or Granular Quartz, with four subdivisions.

This is what Dana calls Phase II.

The Sparry limestone is here replaced, the Black slate is separated from the Taconic slate, and the whole series is turned upside down. This order is now in accordance with the indications of the section given on page 145 of his Report on the Second District, and conforms with the theory of an overturn, as maintained by H. D. Rogers.

In this volume, the Taconic is recognized in Rhode Island, in Maine and in Michigan.

In another publication of about the same date* he makes a historical remark on the origin of the Taconic system, referring to the article in Disturnell's State Register. "In making up our notes for this object," he says, "we found it necessary to fix upon some general subdivisions of the rocks belonging to the State. We drew up an abstract of the plan, and submitted it to the criticism of the Rev. Prof. Dewey, of Rochester. . . . Professor

**American Quarterly Journal of Agriculture and Science*, vol. iv, 1846, p. 202.

Dewey approved of the division proposed, in the main. It resulted in separating the rocks in the vicinity of the Taconic range, both from the Primary and the New York Transition, as we then called them.

1848. Professor James Hall having described* *Atops trilineatus* of Emmons under the name of *Calymene beckii,* and referred it to the Hudson River group, and having also described in the same work (p. 256) *Elliptocephalus asaphoides* under the name of *Olenus asaphoides*, and referred it likewise to the Hudson River group (see especially Hall's foot-note, p. 257) professor Emmons, "with other specimens more perfect" presented to the American Association, a new and detailed description of *Atops trilineatus,* and a parallel description of *Triarthrus* (*Calymene*) *beckii*† pointing out what appeared to be important differences‡. He also discussed *Elliptocephalus,* and indicated technical distinctions between that genus and *Olenus* and *Paradoxides* (p. 18). In the same connection he repeated that the tenability of the Taconic system rested on structural and mineralogical evidence "far more important than the presence or absence of certain fossils"—meaning evidently, these fossils.

1855. In his "American Geology," the second part of which appeared this year,‖ the Taconic system receives a new presentation. The following is a synopsis of the System as then understood:

Upper Taconic.	Black slate of Bald mouniain,	I. Cambrian.
	Taconic slate,	III. I. Hudson slates and Cam.
Lower Taconic.	Magnesian slate,	III. Hudson slates.
	Stockbridge L. includ'g Sparry L.	II. Lower Silurian.
	Granular Quartz.	I. Cambrian.

(I have added on the right, the equivalences as laid down in 1888, by professor J. D. Dana).

This is styled by professor Dana, Phase III; but the only change made since Dr. Emmons' last publication is the omission of the "Sparry Limestone," as in the "Tabular View," at the end of his Report on the Second District—this being merged in the "Stockbridge Limestone,"—and the recognition of a division of the system between the fossiliferous and the unfossiliferous portions—giving us "Upper" and "Lower" Taconic. There were two reasons

Palaeontology of New York, vol. i. p. 252., pl, lxv, figs, 4a-e.

†*Proc. Amer. Assoc.*, 1848, pp. 16-19.

‡ In his judgment of lack of identity, he had been sustained by S. S. Haldeman, chairman of a committee of the Association of American Geologists and Naturalists, a pointed to consider the question (*Amer. Jour. Sci.* II, v, 117, 1848). This judgment fessor Hall opposed (*Amer. Jour. Sci.* II, v, 322, 1848.)

‖ *American Geology*, Part II, 850 pp., Albany, 1855. pp. 1-122.

for inverting the order as originally given : 1st, evidence of an overturn, as all along argued by Rogers, and as shown by the diagram given by Emmons himself ; 2d, the discovery of fossils in the Black slate, which Emmons had always merged in the Taconic slate, or had closely associated with it (*Ag. Rep., 63*). Thus the Black and Taconic slates now stood at the top, but their close chronological association was an erroneous assumption—the former only belonging truly to the sub-Potsdam series. As Dr. Emmons excluded the Potsdam sandstone from the Taconic, and as the Granular Quartz has proved to be Potsdam sandstone, the Black slate was all that he had thus far really brought into the sub-Potsdam Taconic. This Black slate of Bald mountain, Rensselær county, was now the only imperishable nucleus of the Taconic system as conceived—however Dr. Emmons believed. The so-called Lower Taconic was pronounced azoic.

The following points taken from the "American Geology" (p. 122) embody the most important features of the system as then understood by its author: 1. "Its series divided into groups are physically unlike the Lower Silurian series; 2. "It supports unconformably at numerous places, the Lower Silurian rocks." 3. "It is a vital system, having been deposited during the period when organisms existed"; 6. It "carries us back many stages further in time, when life gave vitality to its waters, than the Silurian." To the Bald mountain locality of trilobites he here added one in Augusta county, Virginia, from which he described *Microdiscus quadricostatus*. He also described four marine plants, 22 graptolites and six molluscs.

Keeping in mind the black slate of Bald mountain, which had yielded two species of trilobites regarded by Emmons as sub-Potsdam in age, though described by Hall as of Hudson River age, it is interesting to note the discovery, about this time, of other trilobites in the Black slates of West Georgia, Vermont, lying within the region claimed by Emmons as Taconic. These falling, after two years, into the hands of professor Hall, were also described by him* as belonging to the Hudson River group. By this authority the beds were thus made equivalent to the Bald mountain Black slate. The names given these trilobites were *Olenus thompsoni, O, v ermontana* and *Peltura holopyga*, now determined by Walcott as *Olenellus thompsoni* Hall, *O.* (*Mesonacis*) *vermontana* Hall sp. and *Bathynotus holopyga* Hall (*Amer. Jour. Sci.* III, xxxvii, 389, May, 1889). These were new accessions to the real

**Twelfth Ann. Rep. New York Regents*, 1859, 59-62. On the age of the rocks see *Pal. N. York*, vol. III, p. 94; compare also *id.*, p. 83.

Taconic, for, though made Silurian by Hall, they were recognized by Barrande as primordial or sub-Silurian types. A real sub-Potsdam Taconic existed, therefore, in 1854, in Rensselaer county, New York, and in West Georgia, Vermont, not to mention Augusta county, Virginia. That fact was embraced in Dr. Emmons' claim.*

1859. We have no documents of this date from the pen of Dr. Emmons, showing his use of these primordial trilobites as vouchers for the existence of a real Taconic system. We find no recorded views from him on the publication made by Prof. Hall in 1859; but in his Manual of Geology† (p. 88) the preface of which is dated May 1, 1859, a large trilobite is figured under the name of *Paradoxides brachycephalus*, which, as suggested by professor C. H. Hitchcock in 1881,‡ is identical with *Olenus thompsoni* Hall.

This publication antedates that of the *Twelfth Regents' Report.*‖ The evidence is, therefore, that independently of work done by others in Vermont, and before their results were published, Dr. Emmons had become acquainted with, delineated and published sub-Silurian trilobites within the Vermont area over which he had extended his asserted sub-Potsdam Taconic system. The Georgia slates now beginning to yield the palaeontological evidence of their age, were part of the "Primitive argillaceous slate" of professor Dewey;§ the "Primitive argillaceous slate" of Dr. E. Hitchcock;** the "Black slate" and "Taconic slate" of Dr. Emmons in various publications on the Taconic system.

1860. However, in a note at the end of the second edition of his Manual of Geology (p. 280) he says: "The slates or shales referred to (in the *Regents' Report* for 1859) in northern Vermont, as constituting a new series above the so-called Hudson River group, instead of ranking thus high in the geological scale, are really sub-Silurian, as is fully proved by the overlying calciferous sandstone.

*The Taconic system was maintained in the *Report on the Geological Survey of North Carolina*, 8 vo. 1856, pp. 49-72—reviewed in *Amer. Jour. Sci.* II, xxiv, 427-430.

†*Manual of Geology*, By E. Emmons, 290 pp. 8 vo, Philadelphia, 1860.

‡*Geology of Vermont*, vol. 1, 367.

‖According to Prof. Hall, the whole of the XIIth *Regents' Report* was published previous to Sept. 20, 1859. Mr. Billings gives Oct. or Nov. for the date of publication (*Canadian Naturalist*, vi, 316) though the date on the title page is March 15, 1859—evidently the date at which the printing began. This document purports to be "some of the results of investigations made during the years 1855, '56, '57 and '58 by James Hall" and a note states that they "are already printed in the third volume of the *Palaeontology of New York*." The transmission of this volume to the governor, nevertheless, is dated September, 1859," showing that though "printed," it was not published earlier than the *Twelfth Regents' Report*.

§*Geological Map of Berkshire, Mass; Columbia and Rensselaer counties, N. Y.*, Amer. Jour. Sci., viii, 124.

***Geological Report of Massachusetts*, 1832.

. . . We now know the following trilobites, all of which belong to a slate beneath the Calciferous, viz: *Atops punctatus*, *Elliptocephalus* (*Paradoxides*) *asaphoides*, *Paradoxides Thompsoni*, *P. Vermontanus*, *P. macrocephalus*, *P.* (*Pagurus*) *quadrispinosus* and *Microdiscus quadricostatus*."

This extension and validity were given the Taconic system during the life of Dr. Emmons, and almost wholly through the persistence, ability, and force of his own efforts. The geologists of the country, save Vanuxem, Jewett and Billings, were unitedly against him. The most prominent palæontologist of the country had referred the Georgia trilobites to the upper part of the Hudson River group. The distinguished structural geologist of Canada, Sir William Logan, had rendered his testimony that the shales affording the fossils were "part of a series of strata which he is (was) inclined to rank as a distinct group above the Hudson River proper.* Only one authoritative voice was raised in vindication of Dr. Emmons' long contested claims. That voice came from across the ocean, and almost in tones of reproach for American palæontology, in failing to recognize the principles of order which it had professed to recognize in the succession of organic life, gave utterance to the sentiment: "Si le Dr. Emmons fait encore de la géologie c'est pour lui une belle occasion pour réproduire ses anciennes observations et ses idées avec plus de succés q'en 1844.†

No public documents relating to the Taconic, of later date than 1860, issued from the pen of Dr. Emmons. He went to North Carolina in September, 1860, as State Geologist, and remained within the Confederate lines during the civil war, "until he died, in 1863, at his plantation in Brunswick county, on the first of October". Mr. Marcou, however, maintained a correspondence with him until January 28, 1861, and from these letters I quote a few passages.||

In a note dated Raleigh, Nov. 10, 1860, he says : "I do not think him (Barrande) right in maintaining that his Primordial Group is a part or parcel of the Silurian . . . The Lower Silurian is strictly unconformable to every part of my Taconic series." Writing the next day, he continues : "Perhaps I did Barrande injustice. . . I find that after all, his Primordial Group is only Lower Silurian. I conceive we have exactly his Primordial Group in the

*Twelfth Report N. Y. Regents, p. 62, note.

†Letter of M. Barrande to M. Marcou, 14th Aug., 1860, (*Proc. Amer. Acad.*, 1885. p. 182) "On the Primordial Fauna and the Taconic System of Emmons." Also, in part, *Proc. Boston Society Nat. Hist.* vii, Dec. 1860, 369-375.

||The letters are published, with much other correspondence, in *Proc. Amer. Acad.*, xii, 1885, pp. 181-224.

band of slates containing the *Paradoxides.** On the 28th of December, referring to a communication rejected by the editor of the *American Journal of Science,* in which were embodied some comments on the Huronian system of Logan, he says: "I claimed that the Huronian was only the Taconic system." On January 23, 1861, he writes: "It was ten years ago, I think, when I claimed Logan's Huronian system as nothing more than the Taconic. . . The acknowledgment of the Primordial of Barrande in this country (referring to some concessions of Sir William Logan)† is really one of the finest and best facts in geology, making a co-ordination of American and European rocks so complete and harmonious; I think of nothing I have said or done in this matter; I look upon the harmony of the systems; they are truly worth dwelling upon."

In reference to M. Marcou's proposal to include the Potsdam sandstone within the Taconic, Dr. Emmons writes, January 28, 1861: "Let me declare once for all, that I have not the slightest objection to your view. . . If you believe you can make out a good case with the Potsdam anywhere, I never shall object, for I have no wants except truth."

These noble sentiments close the correspondence, and constitute, so far as I know, the last utterance of Dr. Emmons which passed the lines of a country so soon to become the theatre of bloody war.

Let us now consider the form which the Taconic system had assumed during the lifetime of its author:

Upper Taconic.	Potsdam sandstone (suggested by Marcou, assented to by Emmons).	I. Cambrian.
	Black slate of Bald Mountain and Georgia slates of Vermont.	I. Cambrian.
	Taconic slates.	III. Hudson slates and I. Cam.
Lower Taconic.	Magnesian slate.	III. Hudson slate.
	Stockbridge limestone, including Sparry limestone.	II. Lower Silurian.
	Granular quartz.	I. Cambrian.

*This looks like an admission that Emmons' *Paradoxides* band was Lower Silurian—against which he contended. But though Primordial was Silurian in the extended sense in which Barrande used the term, it was beneath the Silurian as Emmons conceived it. On the previous day he had declared Barrande's Primordial *not* properly Silurian.

†About this time, in a letter to Barrande, dated Dec. 31, 1860, Sir W. E. Logan wrote: "Professor Emmons has long maintained . . . that rocks in Vermont which in June, 1859, I for the first time saw and recognized as equivalent to the magnesian part of the Quebec group, are older than the Birdseye limestone; the fossils which have this year been obtained at Quebec, pretty clearly demonstrate that in this he is right. It is at the same time satisfactory to find that the view which Mr. Billings expressed to you in his letter of the 12th, July, to the effect that the Quebec trilobites appeared to him to be about the base of the second fauna, should so well accord with your own opinions, and that what we were last spring disposed to regard at Georgia as a colony in the second fauna should so soon be proved, by the discoveries at Quebec, to be a constituent part of the Primordial Zone." This, says Barrande (*Documens anciens et nouveaux*, etc. *Bull.* 4 Fev., 1869, p. 320) "is a formal recognition by Sir William Logan, of the Taconic System at the base of the Silurian."

On the right are the parallelisms established by Dana, Walcott and others. The Table shows the Taconic system left by its author in state of incompleteness—even confusion. We find three members whose true positions are above the Potsdam sandstone. But we find also three members whose positions are admitted to be sub-Potsdam—as maintained by Emmons. The mal-position of the Stockbridge limestone was an error of exactly the same magnitude as that of the geologists who would identify the Granular quartz with the Potsdam sandstone, or would make the Black slates of Georgia synchronous with the Hudson River shales. Our science was then in a comparatively crude state, and none of these errors need surprise us. We have ascertained that a real sub-Silurian system exists, and that Dr. Emmons fixed upon three if not four of its members. Such are the facts. Geologists will differ as to the question whether such a degree of success entitles Dr. Emmons to a recognition of the name proposed by him for the real system whose existence he mentally apprehended so well, but whose form he defined so imperfectly.

It is intended to pursue the later history of opinion concerning the Taconic system, as, with the progress of science, the question became more and more palæontological; and if not yet regarded as settled, the discussion is proceeding mainly on palæontological grounds. The principal papers published in the controversy, since the close of the era of the founder—about 1860, will, unless previously quoted, be found cited in the subjoined note.

*1860. Barrande, Joachim.
On the Primordial Fauna and the Taconic system, with Notes by Jules Marcou. *Proc. Bos. Soc. Nat. Hist.*, Vol. VII, pp. 369-382.

1861. Barrande, J.
Documens anciens et nouveaux sur la faune primordial et le système Taconique en Amérique. Paris, 1861.

1861. Hunt, T. S.
On the Taconic system of Emmons. *Amer. Jour. Sci.* II. xxxii, 427-430.

1861. Hunt, T. S.
On some Points in American Geology. *Amer. Jour. Sci.* II. xxxi. pp. 392-414.

1861. Marcou, Jules.
The Taconic and Lower Silurian Rocks of Vermont and Canada. *Proc. Bos Soc. Nat. Hist.*, Vol. viii, pp. 239-253.

1862. Marcou, Jules
Liste additionelle des fossiles du terrain Taconique de l'Amérique du Nord. *Bull. Soc. géolog. de France*, vol. xix p. 746 Paris.

1862. Marcou, Jules
Letter to Mr. Joachim Barrande on the Taconic Rocks of Vermont and Canada, Aug. 1862, pp. 1-15, Cambridge, Mass.

1863. Bigsby, J. J.
On the Cambrian and Huronian Formations. *Quar. Jour. Geol. Soc.*, 36-52, Feb. 1863.

1864. Marcou, Jules
Notice sur les gisements des lentilles trilobitifères taconiques de le Poi nte Lévis au Canada. *Bull Soc. géol. de France*, vol. xxi, pp. 236-250 (Paris.)

1865. Logan, W. E.

On the Geology of Eastern New York [Tour with James Hall.] *Canad. Naturalist and Geol.* . Republished, *Amer. Jour. Sci.*, II, xxxix, 96-98.

1869. Perry, J. B.

A point in the Geology of Western Vermont. *Amer. Jour. Sci.* II, xlvii, 341-349 [Important].

Brainerd and Seely,

The Marble Border of Western New England. *Middlebury Historical Society*, Vol. i. Pt. II. 1885.

Julien, A. A.

On geology at Great Barrington, Mass. *Trans. N. Y. Acad. Sci.* 1887.

1873. Dana, James D.

On the Quartzite, Limestone and associated Rocks of the Vicinity of Great Barrington, Berkshire county, Mass. . *Amer. Jour. Sci.*, III, iv. pp. 362-377; 450-453; v. pp. 47-53; 84-91; vi, pp. 257-278.

1877. Dana, James D.

An Account of the Discoveries in Vermont Geology of the Rev. Augustus Wing. *Amer. Jour. Sci.* III, xii, pp. 332-347; 405-419; xiv, pp. 36-7.

1877. Dana, James D.

On the Relations of the Geology of Vermont to that of Berkshire. *Amer. Jour. Sci.* III., xiv, pp. 37-48; 132-140; 202-207; 257-264.

1878. Prime, Frederick, Jr.

On the Discovery of Lower Silurian Fossils in Limestone associated with Hydromica Slates, and on other Points in the Geology of Lehigh and Northampton counties, Penn. . *Amer. Jour. Sci.* III, xv, 261-269.

1879. Dale, T. Nelson, Jr.

On the Age of the Clay-slate and Grits of Poughkeepsie. *Amer. Jour. Sci.* III, xvii. 57-59.

1879. Dana, J. D.

On the Hudson River Age of the Taconic Schists, and on the dependeut Relations of the Dutchess county and Western Conn. Limestone Belts. *Amer. Jour. Sci.* III, xvii, 375-388; xviii, 61-64.

1879. Dwight, W. B.

On some Recent Explorations in the Wappinger Valley Limestone of Dutchess county, N. Y., *Amer. Jour. Sci.* III, xvii, 389-393.

1879. Whitfield, R. P.

Discovery of Specimens of *Maclurea magna* of the Chazy, in the Barnegat Limestone near Newburgh, N. Y., *Amer. Jour. Sci.* III, xviii, 227.

1880. Lesley, J. P.

A Hudson River Fossil Plant in the Roofing Slate that is associated with chlorite Slate and Metamorphic Limestone, in Maryland, adjoining York and Lancaster counties, Pa., *Proc. Amer. Philosoph. Soc.*, xviii, 365; *Amer. Jour. Sci.* III, xix, 71-2.

1880. Ford, S. W.

Note on the Trilobite, *Atops trilineatus* of Emmons [Holding it distinct]. *Amer. Jour. Sci.*, III, xix, 152-3.

1880. Dana, J. D.

List of Papers on the Taconic System [as at first defined by Emmons] [with statements of points]. *Amer. Jour. Sci.*, III, xix, 153-154.

1880. Ford, S. W.

On the Western Limits of the Taconic System. *Amer. Jour. Sci.*, III, xix, 225-226.

1881. Winchell, N. H.

The Potsdam Sandstone. [Discusses Taconic]. *Viiith Ann. Rep. Minn.* pp. 123-136.

1881. Dana, J. D.

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1881. Marcou, J.

Taconic Rocks of the Border of Lake Champlain. *Bull. Soc. géol. France*, Nov., 1880. Noticed *Amer. Jour. Sci.*, III, xxii, 321-2.

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Geological Age of the Taconic System. *Quar. Jour. Geol. Soc. Lond.*, xxxviii, 397, Abstract *Amer. Jour. Sci.*, III, xxiv, 291-3.

1883. Hunt. T. S.

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Notes on the Geology of the Southeastern Portion of the Province of Quebec. *Can. Rep.* for 1880-1-2, A. pp. 6-7.
1883. Walcott, C. D.
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1884. Walcott, C. D.
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1884. Winchell, N. H.
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1884. Ford. S. W.
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1884. Dana, J. D.
On the Southward Ending of a Great Synclinal in the Taconic Range. (Read before the British Association). *Amer. Jour. Sci.* III, xxviii, 268-275.
1884. Hall, James.
On the Hudson River Age of the Taconic Slates. [Notice of by Dana]. *Amer. Jour. Sci.*, III, xxviii, 311-312.
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1885-7. Dana, J. D.
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On Lower Silurian Fossils from a Limestone of the original Taconic of Emmons. [Amer. Assoc., 1885], *Amer. Jour. Sci.* III, xxxi, 241-248.
1886. Ford. S. W. and W. B. Dwight.
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The History of Taconic investigation previous to the work of Professor Emmons, (Address, Berkshire Historical Soc., Feb. 1885.) *Amer. Jour. Sci.* III, xxxi 399-401.
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Classification of the Cambrian system of North America (Read before National Academy of Science, Washington, Apr. 23, 1886) *Amer. Jour. Sci.* III, xxxii, 138-157.
1886. Walcott, C. D.
Second Contribution to the Cambrian Faunas of North America, 369 pp. 8vo. with 33 plates. *Bull.* No. 30. *U. S. Geol. Surv.*
1886. Hunt, T. S.
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1887. Winchell, N. H.
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Palæontological Observations on the Taconic Limestone of Canaan, Columbia county, N. Y. (Amer. Assoc. Aug., 1886,) *Amer. Naturalist*, 1887, p. 270.
1887. Walcott, C. D.
Geologic Age of the Lowest Formations of Emmons' Taconic System. Read before Philosophical Soc. Washington, Jan. 15, 1887. Abstract, *Amer. Jour. Sci.*, III, xxxiii, 153-4.
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1887. Irving, R. D.
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Notes on the part of the Huronian Series, in the neighborhood of Sudbury Canada. *Quar. Jour. Geol. Soc.* London, Feb. 1888, pp. 32-35.
1888. Marcou, Jules.
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1888. Winchell, N. H.
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1888. Selwyn, A. R. C.
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[Use of the term Taconic, in Report to International Committee] *Amer. Geologist*, ii, 208-211.
1888. Walcott, C. D.
On the Taconic System of Emmons [Compiled as an expression of opinion] *Amer. Geologist*, ii, 215-219, with Note by N. H. Winchell, 220-224.
1888. Vogdes, A. W.
Some Forgotten Taconic Literature. *Amer. Geologist*, ii, 352-355.
1888. Walcott, Charles D.
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The Taconic of Eastern New Foundland. *Amer. Geologist*, iv, 121-125.
1889. Walcott, C. D.
Stratigraphical position of the *Olenellus* Fauna in North America and Europe. *Amer. Jour. Sci.*, III, xxxvii, 374-392; xxxviii, 29-42.
1889. Dwight, W. B.
Recent Explorations in the Wappinger Valley Limestone, No. 7. In the Millerton-Fishkill Limestone Belt; also in a Belt near Rhinebeck. *Amer. Jour. Sci.*, III, xxxviii, 139-153.
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Fossils of the western Taconic Limestone, in the eastern part of Dutchess county, N. Y. (Announcement.) *Amer. Jour. Sci.*, III, xxxix, 71.

DOUGLASS HOUGHTON.

1831. Dr. Houghton's earliest record in respect to the rocks of Michigan is found in his report to the Secretary of War as Botanist of Schoolcraft's Expedition.* Speaking of the copper of lake Superior, he says: "After having duly considered the facts which are here presented, I would not hesitate to offer as an opinion that the trap rock formation was the original source of the masses of copper which have been observed in the country bordering on Lake Superior; and that at the present day, examinations for the ores of copper could not be made in that country with hopes of success, except in the trap rock itself; which rock is not certainly known to exist in any place upon lake Superior other than Kewena point." This opinion on the source of the native copper he had subsequently abundant opportunity to confirm, though opposed by much scientific incredulity.

1840. In his Third Annual Report on the geology of Michigan, dated February 3, 1840, summarizing observations of 1839, Dr. Houghton treats of the "Upper Peninsula." Under the head of "General Geology of the South and Southeasterly Part of the Upper Peninsula,"† after describing the distribution of the "Primary rocks" in Michigan, he says: "The immense Primary region of which the line described may be considered as it were, a single point, stretches nearly continuously, many hundred miles northwesterly, skirting a portion of the shores of lake Superior, and in conjunction with the trap rocks, constituting the highlands between that lake and lake of the Woods. From these highlands it stretches a little east of lake Winnipeg, far to the northwest, finally constituting the immense "barren grounds" of the British Possessions. It is also well known that this range of primary rocks stretches in an easterly direction through the interior of the upper province of Canada" (p. 11).

This is the earliest general location of the eastern nucleus of the continent.

1890. Marcou, J.
The Lower and Middle Taconic of Europe and North America. *Amer. Geologist*, v, 357-375; vi, 78-102, 222-233.

1890. Winchell, N. H. and H. V. Winchell.
The Taconic Ores of Minnesota and Western New England. Read before the Geological Society of America, Aug. 19. *Amer. Geol.* Nov. 1890.

1890. Winchell, N. H.
What Constitutes the Taconic Mountains? Read before Sec. E, Amer. Assoc. Adv. Sci., Aug. 22, 1890. *Amer. Geol.*, vi, 247.

*Nov. 14, 1831. Also Henry R. Schoolcraft, *Discovery of the Source of the Mississippi* New York, 1834, pp. 287-292.

†*Senate Document* No. 8, 1840, p. 10.

Some further but disconnected quotations will be introduced.

"On the mainland at these 'narrows' [the place where the current of Ste. Marie's river meets the slack-water of lake Huron] and extending for several miles, the knobs are composed of compact greenstone, occasionally partaking of a sub-slaty character, and under which circumstances, the rock bears a close analogy to some of the varieties of primary argillite."

"On the northern part of the island of St. Joseph, a fraction of the southeastern part of Sugar island, and a portion of the main land on the east, the place of the hornblende rock is supplied by granular quartz rock, usually white, but sometimes passing to a reddish or deep red color."

"In the range of hills bounding the easterly side of Great Lake George, talcose slate was observed, but to what extent it exists I am unable to say" (p. 13).*

It appears that Dr. Houghton's conception of "Primary rocks" was rather broad. The granular quartz rock mentioned is now known to be a westward extension of the "Huronian" quartzites of the Thessalon valley in Canada. The "talcose slate" on the other hand, probably belongs to the Marquette iron-bearing series which by the present writer has been suggested to be an older system than the Huronian. It is worthy of note also, that Dr. Houghton reports the "Lake Superior sandstone" as resting "against and upon the Primary range of the Ste. Marie's river." That is, at one point the "talcose slates" (Marquette series) rest in contact with the gneisses; at another, the overlying quartzyte (Huronian) extends over to the gneiss; and at another, the still higher sandstone (Palæozoic) reaches over to the gneiss. Thus, it is unsafe to conclude that the formation resting on the gneiss at any particular spot is the one historically next in order of age.

1841. In his report for the following year, † he continues his description of the Northern Peninsula. His conception of Primary rocks appears more restricted, for he says they "are chiefly granite, syenite and syenite granites." (p. 15.) After describing the vast development of "Trap Rocks," he recognizes a group designated "Metamorphic Rocks." "Flanking the Primary rocks on the south," he says, "is a series of stratified rocks consisting of talcose, mica

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* In view of the recent extensive employment of "field stones" in some parts of the state, in the walls of substantial structures, the following quotation from this report possesses interest: "In the immediate vicinity of the surveyed line of the Ste. Marie's canal. transported masses of granite, hornblende, sienite and quartz rocks abound, and they may be economically employed for the construction of the proposed locks, and will make an enduring structure." (p. 15).

†Senate Document No. 16, 1841.

and clay slates, slaty hornblende rock and quartz rock; the latter rock constituting by far the largest proportion of the whole group." These represent the group of rocks in the Menominee region, which Dr. Emmons so eagerly accepted as representatives of the Taconic system in Michigan.

The following is an interesting early notice of the mode of occurrence of serpentine. "In traversing the country southeasterly from Little Presqu' ile, the point referred to as the most southeasterly prolongation of the granite, this last rock passes almost insensibly into a serpentine rock* which has a regular jointed structure, sometimes approaching to stratification; continuing in the same direction, we find a series of hornblende slates, talcose, mica and clay slates, resting against the serpentine rocks; and still farther to the southeast, the rock becomes almost uniformly quartz. The rocks of this group dip irregularly to the south and southeast, while the cleavage of the slate is very uniformly to the north," (p. 17.)

A gradual passage from granite to "greenstone" is noted as follows: "As we proceed northwesterly from the southeast boundary of the Primary, over the several broken ranges of hills, we find the character of the rocks in mass almost imperceptibly changing. The quartz as a mineral gradually forms a less important part, and it finally almost wholly disappears, leaving a binary compound of feldspar and hornblende, which then assumes a granular structure, constituting greenstone. The intermediate rock between the syenite and greenstone ranges may not inappropriately be called a syenitic greenstone," (p. 23.)

The granitic rocks are intersected by dikes which can be traced continuously and with increasing abundance, into the greenstone masses, showing the granitic ranges to be the oldest (p. 24).

In reference to amygdaloids he says: "I am disposed to refer the origin of much of the amygdaloid rock to the fusion of the lower portion of the sedimentary rocks referred to, for the reason that as we pass south from the junction [receding from the sedimentary rocks] the amygdaloid rocks wholly disappear, their places being supplied by greenstone; and again, so intimately are they blended that it is frequently impossible to determine where the amygdaloid ceases and the upper sedimentary rocks commence. Fragments of the sedimentary rocks, the characters of which can be clearly recognized, are not of rare occurrence, imbedded in the amygdaloid rock, a circumstance which, although by no

*The curious history of opinion concerning this much discussed rock is compiled by Dr. Wadsworth in *Bull. Mus. Comp. Zool.*, Geol. Series, I, pp. 60-65.

means conclusive, should not be overlooked in considering the subject" (pp. 27 and 28).

Of the conglomerate rock he says: "It may without doubt be considered as a trap tuff, which was gradually deposited or accumulated around the several conical knobs of trap during their gradual elevation" (p. 33). It is very variable in thickness. There is "scarcely a pebble of any other rock than trap." They are cemented by "a mixed calcareous and argillaceous cement more or less colored by iron, and exceedingly firm. The conglomerate is "imperfectly stratified in masses of immense thickness," in its maximum a little east of Montreal river, estimated at 5,260 feet, (pp. 34, 35).

The formation described as "mixed conglomerate and sandrock" "is made up of an alternating series of conglomerate and red sandstones which rest conformably on the conglomerate rock last described" and "in strictness should probably be considered as a member of the conglomerate itself" (p. 18). Its greatest observed thickness is 4,200 feet. The conglomerate beds resemble in all respects the underlying conglomerate, and the intervening sandstone beds are composed of the same materials, but are sometimes ripple marked, and were thus evidently deposited in shallow water.

These sandstone beds are very distinct in composition from the "red" and "grey" sandstones higher in the series" (pp. 19, 37).*

It will serve to convey an idea of the extent of Dr. Houghton's researches in the Upper Peninsula to state that the *Exec., Doc.*, 1849-50, Part III, contains (p. 880), the following among Hough-

*The "red sandrock" associated with "shales" is much more quartzose than the beds intercalated with the conglomerate. It attains a maximum thickness of 6,500 feet. "On the southeast side of Keweenaw bay, near its head, an argillaceous rock appears" "evidently embraced in, or rather may be said to constitute a member of, the sandstone series." It is sometimes, "in the form of a slate," though usually it "closely resembles indurated clay." It can be cut with the knife, and the Indians have long used it as a pipestone. A similar rock appears at several other points in the interior. These slates are shown by his notes of 1845, to pass under the sandstone.] The "Upper, or Grey Sandrock" is no part of the Lake Superior sandstone. While the latter dips northeasterly, this dips southeasterly, and is conformable with the overlying limestones. The "Grey Sandrock" forms a range of hills extending westward from Pt. Iroquois to the Pictured Rocks, where they abut upon the shore of the lake. It is Dr. Houghton's opinion, therefore, that the Pictured Rocks are a higher formation than the Red Sandstone, generally contemplated as the "Lake Superior Sandstone" (19,42.) The Lake Superior sandstone Dr. Houghton was at first inclined to parallelize with the "Old Red Sandstone" (*Report*, 1838); but, in a paper read before the Association of American Geologists in 1843, he assumed it as identical with the "New Red Sandstone" (*Amer. Jour. Sci.*, xlv, 160.) Later he synchronized it with the Potsdam sandstone of New York, and this view was embodied in his notes of 1845 (*The Mineral Region of Lake Superior*, 1846, by Jacob Houghton.) The statement is contained in a report by Bela Hubbard—page 118—compiled from Dr. Houghton's notes;) Also, *Executive Docs.*, 1849-50, pt. III, p. 839. The same was noted on the plats of 1845. See also the testimony of Foster and Whitney, *Report on the Geology of the Lake Sup. Land Dist.*, Pt. II, p. 138, and *Proc. Amer. Assoc. Adv. Sci.* May, 1851, p. 23.

ton's results: 1. "A Geological Map of the Townships of the Northern Peninsula of Michigan subdivided by D. Houghton, D. S. in the year 1845." (This covers Keweenaw Point.) 2. "Geological Map of Township Lines in the Northern Peninsula of Michigan, surveyed by Wm. A. Burt, D. S. in the year 1845, for D. Houghton, under said Houghton's contract for surveys with reference to Mines and Minerals" (The region on Little Bay de Noquet and along the Escanaba river and to lake Superior.) 3. "Geological Map of a District of Township Lines in the Northern Peninsula of Michigan, surveyed by Wm. A. Burt in the year 1846." (Region between the Escanaba and Menominee rivers.) Also (p. 896.) 1. "Geological Map of a District east and west of the Ontonagon, subdivided by Messrs. Higgins and Hubbard under a Contract bearing date April 23, 1846" (From Portage lake to Carp river.) 2. "Geological Map of the District subdivided by Messrs. Hubbard and Ives, under Contract bearing date September 7, 1846." (The Region from Presqu' ile to L' Anse.) These six maps were produced under the system of combined linear and geological surveys inaugurated by Dr. Houghton. Thus nearly the whole of the Upper Peninsula had been geologically mapped before the signing of the contract with Foster and Whitney, and without including the results of Dr. Jackson's survey. Mr. Hubbard gives also, five handsomely drawn sections from lake Superior, across the country southward, besides five lithographed views.

The following is Dr. Houghton's latest view of the succession of rocks in the Upper Peninsula of Michigan:

6. Upper or Gray Sandstone (Houghton, 1841, pp. 19, 41) not conformable with next below.

5. Lower or Red Sandstone and Shales (Houghton, 1841, pp. 18, 37). Identified with Potsdam Sandstone.

4. Mixed Conglomerate and sandstone (Houghton, 1841, pp. 18, 35).

3. Conglomerate (Houghton, 1841, pp. 17, 33).

2. Metamorphic rocks (Houghton, 1841, pp. 16, 31). Quartzite, Argillite, Talcose and Clay slates, Mica slate.

1. Primary rocks (Houghton, 1841, pp. 15, 23). Granite, Gneiss, Syenite and Syenitic Granite.

Numbers 6 and 5 are probably both representatives of the New York Potsdam. Numbers 4 and 3 are the Keweenawan System of Chamberlin and Irving, and number 2 occupies the place of the Taconic system of Emmons.

EDWARD HITCHCOCK.

1833. In his Final Report on the Geology of Massachusetts,* Professor Edward Hitchcock enumerates, among others, the following rocks or groups of rocks mineralogically considered: Graywacke, Argillaceous slate, Limestone, Scapolite rock, Quartz rock, Mica slate, Talcose slate, Serpentine, Hornblende slate, Gneiss — all which are stratified; Greenstone, Porphyry, Syenite and Granite — which are unstratified. Of the Berkshire limestone, he thinks a part is "primitive, in the Wernerian acceptation of the term, for it is interstratified with gneiss and mica slate" (p. 297). But the mica slate in its westward extension becomes clay slate, and the limestone less crystalline. Passing into New York, the limestone assumes the character of Dewey's "transition limestone."

"But a singular anomaly in the superposition of the series of rocks above described presents a great difficulty in the case. The strata of these rocks almost uniformly dip to the east; that is, the newer rocks seem to crop out beneath the older ones, so that the saccharine limestone associated with the gneiss in the eastern part of the range seems to occupy the uppermost place in the series. Now, as superposition is of more value in determining the relative ages of rocks than mineral characters, must we not conclude that the rocks as we go westerly from Hoosac mountain, do in fact, belong to older groups? The petrifactions which some of them contain, and their decidedly fragmentary [fragmental] character will not allow such a supposition to be indulged in for a moment. It is impossible for a geologist to mistake the evidence which he sees at almost every step, that he is passing from older formations, just as soon as he begins to cross the valley of Berkshire towards the west. We are driven then, to the alternative of supposing either that there must be a deception in the apparent outcrop of the newer rocks from beneath the older, or that the whole series of strata has been actually thrown over, so as to bring the newest rocks at the bottom. The latter supposition is so improbable that I cannot at present admit it" (pp. 297-298). He then supposes two unconformities to have been produced — one at the west base of Hoosac mountain between the gneiss and the quartz rock, and the other farther west, in the valley of Berkshire. He names some difficulties involved in the acceptance of such an explanation, but feels compelled to adopt it provisionally. Moreover, he says, "I am sustained in this opinion by that of Dr. Emmons of Williams College, whose acuteness of observation and accuracy of discrimina-

* Report on the Geology, Mineralogy and Botany and Zoology of Massachusetts. By Edward Hitchcock. Amherst, 1833, Roy. 8-vo, pp. 700.

tion in the various departments of natural history are well known" (p. 300.

Professor Hitchcock frequently touches on questions of metamorphism. In his "Theoretical Considerations" on mica slate, after explaining the strict Wernerian view of the aqueous origin of all the primary rocks, and pointing out the improbability that so many different substances should crystallize out simultaneously from the same solution, he says:

"I am inclined therefore, to the theory which supposes that they were originally mechanically deposited from water, like the existing secondary and tertiary rocks, and that they have subsequently been subjected to such a degree of heat as enabled their materials to enter into a crystalline arrangement, without destroying their structure" (p. 350).

In reference to serpentine, professor Hitchcock advances some suggestions which were singularly in advance of his time. He speaks of prevailing divergences of opinion as to its nature and origin, and decides to describe it in connection with stratified rocks, though he finds it occurring unstratified as well as stratified. He mentions the various circumstances of its occurrence and adds:

"In all cases (except perhaps that at Newport) our serpentines are associated with talc, either pure and foliated, or as steatite, or chlorite slate, or talc and quartz. The two minerals (talc and serpentine) are intimately blended together, and pass into one another by insensible gradations, and in all the cases described by the writers above referred to, talc was present. Is it not natural then, to suspect that serpentine is talc, or talc serpentine, altered by heat? And since the talc is schistose, and the serpentine massive, the latter must have been produced from the former. . . It may be found that serpentine has been produced from various rocks which contained the necessary ingredients. But that heat has been employed in its production, cannot, it seems to me, be reasonably doubted" (pp. 372, 373).

In some "theoretical considerations" concerning gneiss, he says:

"Since gneiss is composed of the same simple minerals as granite, it is natural to infer that both must have had a similar origin. And especially are we led to such a conclusion, when we see in granitic gneiss a gradual passage from the one rock to the other. That granite has resulted from heat instead of aqueous deposition seems to me to be so well established that the opinion that imputes to it such an origin ought no longer to be regarded as hypothesis, but as legitimate theory. . . At present I shall assume that theory to be the correct one which supposes granite to have resulted from the melting down of other rocks; the fused mass having cooled so slowly as to present a confused crystallization. It is at least, a probable supposition, that the rock out of which it was produced was of mechanical origin, and consequently stratified. Now, if the central heat was not sufficient entirely to melt this stratified rock, yet it would be powerfully affected a considerable distance upward from the molten mass. The first in immediate contact with the melted portion would be partially fused, and hence give origin to granitic gneiss. Another portion might be converted into porphyritic gneiss; another, into lamellar; another into schistose, etc. All the rock, we may suppose so near the fluid granite, and so long in contact with it, before cooling, that crystalline would succeed to a mechanical arrangement of all its ingredients, without losing the stratified disposition (p. 400).

In discussing the history of granite, professor Hitchcock states that he infers its igneous origin "from the inclined position of the older stratified rocks; from the manner in which it is intruded among the stratified rocks; from the mechanical effects which it appears to have exerted upon the stratified rocks in its immediate vicinity; from its chemical effects upon the surrounding strata, and from its crystalline structure, and the numerous crystallizations of other substances that have taken place in it" (pp. 509-515).

1840–1. The inversion of the strata of the Appalachian system is referred to again in his Elementary Geology.* Speaking of overturned strata in the Alps, he says:

"I have no small reason to believe that a similar folding and overturning of the strata have taken place on a vast scale in the United States. Along the western part of the Green and Hoosac mountains in New England, occur interstratified beds of gneiss, mica slate, talcose slate, clay slate, limestone and older Silurian rocks which are either perpendicular or have a high easterly dip; and yet the oldest members of the series are found along the eastern side of this belt, and the strata become newer and newer as we go westerly; that is, the oldest rocks lie apparently over the newer ones. These appearances present themselves nearly the whole distance from Connecticut river to Hudson river—a breadth of nearly fifty miles." He then describes the folding, overturn and denudation which would result in the present structure and surface aspects. "It appears further, from the Geological Reports of Professors Mather on New York, Henry D. Rogers on New Jersey and Pennsylvania, William B. Rogers on Virginia, and Troost on Tennessee, that these same

*Elementary Geology. The Preface to the first edition is dated August 1, 1840; that of the third edition, April, 1842. I quote from the third, 12mo., pp. xii 352.

rocks with similar inversion of their dip, occur in all those states, forming a considerable part of the Appalachian mountains; and that in fact, they extend almost uninterruptedly from Canada to Alabama—a distance of nearly 1200 miles; and if the above theory of the folding and inversion of this belt of rocks be correct in the latitude of Massachusetts, it is without doubt, true over this vast extent of country."*

The subject of inverted arrangement of the Appalachian strata was under careful consideration at this time, by the brothers Rogers, as well as by Dr. Hitchcock. The earliest enunciation of the conception of an inverted fold had been made by Dr. Hitchcock in 1833. His conception however, was not identical with that of the brothers Rogers. He spoke only of a single anticlinal, while the Rogers brothers saw a succession of anticlinals all tilted westward across the main mass of the Appalachians. In an address delivered in 1841, he said:†

"There is no small reason to believe, indeed, that on the western side of the continent, from Cape Horn, to the northern Arctic Ocean, *one vast anticlinal axis exists,* along the crest of the Andes and the Rocky mountains. Subordinate and perhaps intersecting systems of strata will undoubtedly be found along the extended line, but this appears to be the grand controlling, and probably the most recent, uplift of the continent. . . . The Appalachian range of mountains forms *another anticlinal ridge,* extending northeasterly through New England, and not improbably to Labrador" (pp. 264-265).

In the Elementary Geology before quoted, Dr. Hitchcock amplifies his defense of the metamorphic theory then recently introduced into geology by Alexander Brongniart. The main points stated are briefly these: 1. It shows why, amid so much evidence of chemical agency in the formation of the primary rocks, there is still so much proof of the operation of mechanical agencies. 2. It shows why silicates predominated in the earlier periods of the globe, and why limestone and carbon were more abundant at the later periods. 3. It explains the absence of organic remains in the primary stratified rocks. 4. It explains, too, the reason why carbon is much less abundant in the older than in the newer rocks. 5. It explains the imperceptible graduation of gneiss into granite" (pp. 259-61).

**Elementary Geology*, pp. 36, 37. The subject is also taken up in his Anniversary Address (cited below,) p. 268.

†First Anniversary Address Before the Association of American Geologists at their Second Annual Meeting in Philadelphia, April 5, 1841. *Amer. Jour. Sci.*, vol. xli, pp. 232-275.

In the Anniversary Address from which I have quoted, Dr. Hitchcock considers briefly the origin of dolomytes :

"As to that portion of this field [of dolomite and dolomitic limestones] which has fallen under my observation, I find that with one or two unimportant exceptions, all the cases of dolomitized limestone occur either in the vicinity of a fault or of unstratified rocks, or of the oldest gneiss. The pure dolomite is usually found where there is reason to believe extensive dislocations of the strata occur ; and the marks of stratification in the limestone disappear nearly in proportion to the amount of magnesia which it contains, so that the pure dolomite shows scarcely any traces of it. I doubt not that similar conclusions will follow an examination of other parts of this deposit, so remarkably uniform in the geology of this continent ; — and moreover, these conclusions correspond to the history of dolomitization in Europe. They seem to render probable the theory of sublimation from the interior of the earth."*

1859. In the Final Report of the Geology of Vermont,† Dr. Hitchcock, who assumed the responsibility, as he tells us, though most of the field work was done by others, takes up early in the report, the subject of "The Metamorphism of Rocks" (p. 22). In the following language he sets forth his general conception of the *modus operandi* of hypogeal metamorphism.

"If the globe was once in a molten state, the crust which first formed over its surface must have been some kind of unstratified rock. When it became coal enough to allow water to condense on the surface and form oceans, the waves would wear away portions of the rock, and deposit the fragments in the form of gravel, sand and clays. These by the action of internal heat might be hardened, and become conglomerates, sandstones and shales. If new beds of materials should be thrown upon these strata it would cause the internal heat to penetrate further upward into the conglomerates, sandstones and shales, and, by the help of water, render the rocks plastic and convert them from mechanical into crystalline rocks, without destroying the planes of stratification, though generally obliterating all traces of organic structures which they might have contained, and changing the laminated structure into foliation and cleavage. After all this, water may have acted mechanically on these strata, wearing them away, and forming other deposits of puddingstones, sandstones and shales. Meanwhile also, the inter-

*Amer. Jour. Sci., xli. 240.

†*Report on the Geology of Vermont, Descriptive, Theoretical, Economical and Scenographical.* By Edward Hitchcock, Edward Hitchcock, Jr., Albert D. Hager, Charles H. Hitchcock. 2 vols. 4to. Claremont, N. H., 1861. The preface is written by Dr. E. Hitchcock, and dated Oct. 1, 1859, and Oct. 2, 1860.

nal heat working farther upward, as it certainly would by the accumulation of new beds of detritus, might melt over the lower beds of the strata, converting them into unstratified rock. And thus might the same materials have been subject to repeated and most thorough metamorphosis" (p. 22).

The writer then proceeds to an account of the "agents of metamorphism," heat and water, recalling the well known results of experiments and reasoning, and treats with considerable detail the evidences of "a former plastic condition of the rocks". He cites numerous observations, showing that rocks and rock-constituents must have been reduced to a plastic or semi-plastic condition, subsequent to their original consolidation, and so continued for a great length of time", In this connection he cites numerous instances of pebbles which have been elongated and flattened—some even at length being "converted into the silicious folia of schists, and the cement into mica, talc and feldspar". He refers to the pebbles near Newport, Rhode Island; others at intervals along the western side of the Green mountains, and especially a locality in Plymouth, Vermont, where pebbles occur under such forms as to indicate a state of plasticity. In Wallingford the beds of conglomerate thus altered alternate with beds of talcose and mica schist (pp. 28–38, 476). Some of the facts point toward the inference that schists and gneisses even may have originated from the extreme flattening and elongation of the pebbles of an original conglomerate, though as a fact, pebbles had not at that date been found actually occurring in gneiss. Dr. Hitchcock expects that such views would "be pronounced preposterous by able geologists*". In a syenitic rock, however, found in Vermont and Massachusetts, undoubted pebbles had been observed. Other facts have been noted by the writer: See, Conglomerates enclosed in Gneissic Terranes, *Amer. Geologist*, iii. 153-165; 256-261; *Sixteenth Ann. Rep.*, Minn. pp. 218-222, 334. He says:

"We define this rock as a conglomerate with a cement of syenite or granite, or as a syenite or granite with pebbles in it, sometimes thickly and sometimes sparsely disseminated". . . . "These facts certainly give great plausibility to the view which supposes granite and syenite to be often the result of the metamorphosis of stratified rocks" (pp. 40, 41; ii, 565, 566.*)

In connection with the discussion of metamorphism the writer

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*Dr. Hitchcock's expectation has found fulfillment in the dissent recorded by Dr. M. E. Wadsworth *Bull. Mus. Comp. Zool.*, Geolog. Series, i; B. S. Lyman, *Proc. Amer. Assoc. Adv. Sci. 1866, p. 83.*

*See W. B. Rogers' views in opposition to those of Hitchcock stated in *Proc. Bos. Soc. Nat. Hist.* 1861 and *Amer. Jour. Sci.*, II, xxxi, 440-442, May, 1861.

reminds us of an inference which is too obvious to have fallen into such general forgetfulness. He says:

"Metamorphism shows us that the earliest formed rocks on the globe may have all disappeared. None of the first formed crust may remain. Or, if any of it is left, it would be impossible to distinguish it from subsequent formations. So that the idea of a primary granite or any other rock, in the strict sense of the term, has no foundation in nature" (p. 47.)

In close connection with this subject, we cite some passages from another chapter, touching the nature of foliation. Speaking of the gneissic rocks of Vermont, he says: "In certain districts the strata are exceedingly contorted, and the average dip and strike are the ones that we recorded. There is not a square mile of this rock in the State where there are not more or less of these irregularities. In a few instances, the difficulty of ascertaining the true position is so great that we have not attempted it."

After illustrating a striking particular instance of these contortions, he concludes:

"This state of things suggests two important topics: *First*, Do not these contortions prove that the layers that have suffered this twisting are the strata, and not the bedding of cleavage or foliation? For the beds between cleavage planes are rarely contorted. The strata may be contorted while the cleavage planes cross them with perfect regularity. In fact, the cleavage does not appear to have been produced until the strata had been quietly settled into their present positions, as a general thing." The *second* topic relates to the effect of contortion on calculation of thickness of terranes*.

Speaking of the position of the "red sandrock" of northern Vermont," regarded by Emmons as belonging to the age of the Potsdam and Calciferous, Dr. Hitchcock says:

"Without an exception, it rests upon the Hudson River group. The stratigraphical evidence goes to show that the red sandrock is of the age of the Medina sandstone or Oneida conglomerate. This was the original view of Dr.Emmons, and has since been sustained by Professors C. B. Adams, W. B. Rogers† and W. E. Logan. It is certainly an objection to this view that the characteristic fucoid, *Arthrophycus Harlani*, of the Medina sandstone

*Geology of Vermont, p. 518.

†A communication is cited from W. B. Rogers, which is said to have been prepared for the *Amer. Assoc.* at Albany in 1851, but not published, in which this view is argued (*Geol. Vt.*, p. 326.) This view of Dr. Hitchcock, he states later in his Report, (p. 435) "has now been changed."

has never been found in it." (p. 340.) Compare A. D. Hager's description of "Red Sandrock mountains," (ii, 875.)

In reference to the "Quartz rock" of the older geologists—the "Granular quartz," of Emmons, the "Potsdam sandstone" of the brothers Rogers, of Hall and later geologists, Dr. Hitchcock presents no facts decisive of the question of its position. As to the "Georgia slate"—the "Black slate" and "Taconic slate" of Emmons—the "Hudson River group" of Hall—the "upper part of the Hudson River group, or a distinct group above the Hudson River group" on the authority of Sir William Logan—a "primordial" terrane, as determined by Barrande—Dr. Hitchcock has no decisive facts to offer. He recites the principal data touching the lithological and stratigraphic characters of the group, and acquiesces in the verdict then recently rendered by Hall and Logan in reference to the geologic age, expressly disagreeing with Emmons in regard to any unconformity between the "Georgia slates" and the "red sandrock."

The "Stockbridge limestone" of Emmons, Adams and Thompson is christened "Eolian limestone" (from Mt. Eolus, or Dorset mountain). This is the "Granular limestone" of Dewey, and "metamorphic Trenton limestone" of Rogers, Logan and Hunt. The "Sparry limestone" of Emmons is included in it. As to their geological position, Dr. Hitchcock says: "We incline to the opinion that they must probably be placed as high as that [the Corniferous] formation, or as low as the Lower Silurian, to which last position Mr. T. S. Hunt assigns them. Either position abounds with difficulties, and we are hardly prepared to choose between them," (p. 421). He has changed his view in reference to dolomitization. He says:

"The old notions that it has been done by igneous fusion, or by the sublimation of carbonate of magnesia do not all satisfy the facts as we now understand them," (p. 424). He then quotes from Bischof to the effect that dolomytes can only be regarded as a product of the alteration of limestone in the wet way (p. 424).

The "Magnesian slate" of Dr. Emmons, and of Adams and Thompson, is described by Dr. Hitchcock under "Talcoid schists," because analysis shows that they are essentially aluminous (p. 425). He regards them as probably newer than the Eolian limestone (p. 433).

The theory of the metamorphic origin of granites gains strength in the mind of the author, and he returns to it with new thoughts and new supports. He points out the improbable assumptions of the theory of molten granitic protrusions, save in an exceptional way, (ii. pp. 572, 573), and enforces the arguments for aqueo-igneous fusion of pre-existing rocks as the most probable origin of granites (ii., 574–6). He maintains, 1. The accepted theory of igneo-aqueous softening for recognized schistose rocks needs only an extension in the same direction, to apply to granitic rocks. 2. The order of solidification of the constituents of granite has not been that which would have been followed in a case of cooling from a state of fusion. 3. The existence of hydrated simple minerals, or of such as must have been formed in the wet way, or of such as would undergo partial or entire decomposition, even at a red heat, is an evidence favoring the igneo-aqueous theory. 4. The character of thin tortuous granitic veins, instead of evincing molten fluidity, seems more probably to have resulted from a state of solution or softening in alkaline thermal waters.

Dr. Hitchcock never made an explicit record of his views in reference to the tenability of the Taconic system as a whole. He opposed the earlier views of Emmons in reference to a non-inversion of the strata in western Massachusetts—though at one time wavering on that subject—and is commonly ranked with the brothers Rogers as an opponent of Emmons' claims. But Hitchcock's conception of the assumed overturn was different from that of the brothers Rogers; and Emmons yielded at last, to the evidence of a *folded* overturn. In reference to the position of the "red sandrock" at Highgate and elsewhere, Hitchcock in the earlier portion of his Vermont report, deferred to the positive opinion of W. B. Rogers*, and in this respect was again at variance with Emmons, who held it to lie in the position of the Potsdam sandstone and the Calciferous sandrock†. As to the Georgia slates, which the majority of American geologists had pronounced equivalents of the Hudson River series, or newer, Dr. Hitchcock appears finally to waver. He quotes the changed opinions of Logan, and the positive assertions of Barrande, as well as Hall's explanations of his positions, and as to himself, confesses that he no longer takes sides—though apparently he admits, with Logan, that the Point Lévis rocks are subordinate to the Potsdam, instead of near the middle Silurian. But on still later pages‡, he compiles a resume of the Taconic system, saying, "We shall use the terms which are employed by Prof. Emmons, and shall endeavor to represent his ideas *as they are published*, as faithfully as though we were the amanuensis of an

**Proc. Amer. Assoc.*, Albany, 1851.

†*American Geology*, vol. i, pt. ii., pp. 88, 128, 1855.

‡*Vermont Report*, pp. 434-447.

advocate of the Taconic system." This epitome, therefore, is not compiled in a controversial spirit. Moreover, it soon becomes manifest that some of the reasoning is Dr. Hitchcock's own; that is, he assumes the character of a friend and advocate. He concludes with a statement of "presumptions in favor of the Taconic system": "1. Its similarity to the Cambrian system in Europe." From this is deduced, "2. A presumption that the old doctrine of the Laurentian age of the New England azoic rocks is correct." "3. The Taconic rocks are physically unlike the Lower Silurian." "4, The Taconic system underlies the Lower Silurian." "5. The thicknesses of the Taconic and Lower Silurian rocks do not agree." "6. The organic remains of the Taconic and Lower Silurian rocks are entirely different from one another."

HENRY D. ROGERS.

1842. In their classic memoir "On the Physical Structure of the Appalachian Chain,"* the brothers Rogers say:

"At an early period in the geological surveys of New Jersey and Virginia, we were struck with the great prevalence of the southeasternly dip of the strata, throughout the portions of the Appalachian chain traversing those states, and recognized its dependence on the oblique or inverted folding of the strata. This will appear from the descriptions we have given in our Annual Reports for 1837 to 1839. The important general law of the greater steepness of the dip on the northwestern than on the southeastern sides of the anticlinal axes, became known to us at the same stage of our inquiries and was first announced in the Final Report on the geology of New Jersey, written in 1839, and published early in the spring of 1840" (p. 481).

Another anouncement of these views was made to the American Philosophical Society in January, 1841. †

After adverting to the statements of previous writers that all the strata between the Hoosac mountain [Massachusetts] and the Hudson river lie in an inverted order, drawings were exhibited, proving the existence of numerous closely folded anticlinal and synclinal axes; and the inference was drawn that the inverted dip of the rocks is a result of a folding of the beds at short intervals, and not of one general turning over of the whole series, as suggested by professor Hitchcock. Subterranean igneous action was referred to as having caused this compression and folding of the rocks, and its energy was shown to have been greatest along the

***Transactions of the Association of American Geologists and Naturalists*, 1840, 1841 and 1842 pp. 474-531.

†*Proc. Amer. Phil. Soc.*, Jan. 1, 1841.

Berkshire valley, and the ridges lying to the east. To the same agency was attributed the crystalline condition of the Berkshire marble and of the associated schists and semi-vitrified quartz rock— the first being regarded as merely the blue limestone of the Hudson valley, extensively altered, and the last, a highly altered form of the white sandstone at the base of the Appalachian formations (p. 482).

Speaking of the character of the flexures in the Hudson River division, they say:

"In this belt the flexures are, for the most part, of the closely folded type, and the dip is almost invariably toward the southeast, the compressed and oblique plication of the beds extending equally to the hypogene or primary rocks of the mountains bounding the valley in the east, and to the lower formations of the Appalachian system which occupy the valley itself" (p. 486).

"A feature of frequent occurrence in certain portions of the Appalachian belt, is the passage of an inverted flexure into a fault" (p. 494). "It is an interesting general fact that the space between the axes, or, more properly, the amplitude of the undulations, increases as we cross the chain northwestward" (p. 507).

1844. These views have a bearing on the interpretation of the structure occurring on the east of the Hudson river, within the geographical limits of the Taconic system. In the light of them, professor H. D. Rogers used the following language in reference to the proposal of Emmons.*

"The fixing of a base for the Palæozoic rocks of the United States is a problem scarcely less difficult than that of determining the lower limit of the corresponding system of England, to which the admirable sagacity of Sedgwick has been so usefully directed. Do we possess, in the so-called Taconic system of rocks lying to the southeast of the unequivocally fossiliferous strata at the base of the New York or Appalachian system, an independent mass of formations of an unquestionably earlier date, or are these, on the other hand, but well known lower Appalachian strata disguised by some change of mineral type and by igneous metamorphosis? These Taconic rocks, under the form they assume along the eastern boundary of New York and the western side of Vermont and Massachusetts, have been carefully studied by Emmons, Hitchcock and Mather; all of whom appear to have arrived at different conclusions concerning them.† . . . Professor Emmons considers

**Amer. Jour. Sci.* xlvii. 150. Oct., 1844,

†Professor Mather's conclusions are embodied in the preface to the report on the *Geology of the First District of New York*, 1843, p. viii. Referring to the views of the pro-

the granular quartz, slate and limestone of the Taconic hills and the Stockbridge valley as constituting a distinct group of strata. . . . His principal argument in defense of this view is, that the order of succession of the component members of the group is essentially different from that witnessed in the sandstone, limestone and slate of the Champlain division, and he denies that the theory of plication of the beds, advanced originally by myself and my brother, and applied to this very region, can reconcile the seeming want of agreement. Now it is true that the apparent order of superposition in the Taconic belt is in discrepancy with the well known succession of the Champlain formations, but this is precisely what should arise from the introduction of those complete folds or doublings together of the strata which we have conceived to exist; and I would add that the sections furnished by professor Emmons and professor Mather in their reports, if resolved by the introduction of the flexures, supposed by us, will all of them display, for their western portions at least, the normal order of superposition of the Champlain rocks. This identity of the so-named Taconic System with the formations of the Hudson and Champlain valley was announced by my brother and myself, in the beginning of 1841, to the American Philosophical Society. By the aid of a section from Stockbridge towards the Hudson river, we showed the existence of numerous close anticlinal folds, and thus explained the apparent inversion of the dip, which other geologists had ascribed to one general overturning of the whole series. The plication was shown to be greater along the Berkshire valley and the ridges west; the granular Berkshire marble was identified with the blue limestone of the Hudson valley, but metamorphosed by heat, and the associate micaceous, talcose and other schists were referred, in the language of the communication, to the slates of the formation of the Appalachian system; while the

fessors Rogers, he says: "I concur with them in this opinion. My own observations on these rocks (from the Hoosac mountain to the Hudson) and those of the Hudson valley, conducted with much care throughout their whole extent, in New York, and in Vermont and Massachusetts, through a series of years, have led me to the conclusion that they are metamorphic, and of the age of the Champlain division: that they are the altered limestones, slates and sandstones of that division . . . The white limestone containing plumbago and various crystallized minerals is another point on which there are various views. I have come to the conclusion that it is metamorphic, but in more highly metamorphic state than the dolomitic limestones of the Taconic rocks."

Chapter vii., however (pp. 422-438), is devoted to the "Taconic System". But, at the end, professor Mather remarks: "It will be observed by those who have read the preceding details in regard to the Champlain Division and the Taconic System, that they are considered to be the same rocks, the latter somewhat modified in character by metamorphic agency" (p. 438).

In the chapter on Metamorphic Rocks, he says: "In describing the Taconic rocks separately, I have yielded to the opinion of some of my colleagues who have considered them as interposed between the Champlain Division and the Primary. I can discover no evidence of any such interposition . . . " (p. 440).

semi-vitreous quartz rock of the western part of the Hoosac mountains was stated to be nothing else than the white sandstone (Potsdam sandstone) of the same series slightly altered. . . . It is true Professor Emmons has presented in his report, a series of sections of the strata exhibiting an unconformity at the passage of his Taconic into the rocks of the Champlain division, but I must take the liberty of expressing my disbelief of the existence of any such unconformity, and of observing that, in the prolongation southwestward of this altered and plicated belt, as far as the termination of the Blue Ridge in Georgia, a distance of one thousand miles, no interruption of the general conformity of the strata has ever met the observation of my brother or myself,"

"It would appear thus, that the Potsdam sandstone forms the base of the Palæozoic strata in the latitude of lake Champlain, or at least in the region of the lake and the Mohawk river" (pp. 151-152).

Professor Rogers adds some suggestions which in the light of later palæontological developments, must be regarded prophetic.

"Is this formation, then, the lowest limit of our Appalachian Palæozoic masses generally, or is the system expanded downwards in other districts by the introduction beneath, of other conformable sedimentary rocks ? From the Susquehannah river southwestward, a much more complex series of strata comes in below the bottom of the lowest limestone, than is anywhere seen northeast of the Schuylkill. In some portions of the Blue Ridge belt there are at least four independent, and often very thick deposits constituting one general group, in which the Potsdam, a white sandstone, is the second in descending order. The uppermost of these is an arenaceous and ferriferous slate, many hundred feet thick, in which the only fossil is a peculiar fucoid. Beneath this lies the Potsdam sandstone, and under this again, a mass of coarse sandy slate and flaggy sandstone, amounting sometimes to six or seven hundred feet, below which occurs in Virginia and East Tennessee,* a series of heterogeneous conglomerates. Neither of the two lowest of these masses has yet rewarded research with a single fossil" (p. 152).

* Professor Safford in his admirable digest of the "*Geology of Tennessee*" (pp. 151, 158, 182) described the Potsdam group as composed of: 2*c*. The Knox Group of Shales, Dolomites and Limestones; 2*b*. The Chilhowee Sandstone (Potsdam proper;) 2*a*. The Ocoee Conglomerate and Slates (Eozoic). Below these are the metamorphic rocks, gneiss, mica slate, syenite and chloritic slates. Dr. Safford says; "The metamorphic beds together with those of other groups that are adjacent or neighboring, all appear to follow the same law of dip and strike. The dip is, in the main, at a high angle to the southeast. . . . They all apparently belong to the same system of upheavals. . . . With reference to age, I have no reason for believing that the group within Tennesee includes the metamorphosed beds of any formation of more recent date than the Ocoee conglomerate and shales" (p. 177).

"Adjoining this great mass of arenaceous strata toward the southeast we find throughout much of the broad belt of the Blue Ridge, especially in its prolongation southwestward from the Potomac, a wide expansion of metamorphic strata intersected by innumerable veins and dykes of greenstone and other igneous materials, and displaying almost every grade and variety of alternation in texture and mineral contents. These, after long and careful observation, we have been led to consider as a group of sedimentary beds, still older than the preceding, but forming a part of one and the same unbroken series. Thus, then, in the great group of strata at the base of our lowest fossiliferous series, we are presented with similar and perhaps more striking results of igneous modifying powers than even in that portion of the Champlain system whose metamorphosed rocks constitute the Taconic group. . . . Respecting the phenomena presented in the long belt of rocks here referred to, the question suggests itself whether the so-called Taconic system instead of belonging exclusively to the Champlain division, may not, along with the western border of Vermont and Massachusetts, include also, some of the sandy and slaty strata here spoken of as lying beneath the Potsdam sandstone" (p. 153).

In his final Report on the geology of Pennsylvania, published in 1868,* professor Rogers, in speaking of the Second or Middle Belt of Gneiss, in the southern gneissic district, says: "It would seem as if these minerals had crystallized or segregated from their parent sedimentary materials, under a conflict of forces, the newly awakened crystallizing energies being not always parallel to the original bedding of the deposit, but more frequently oblique to it" (p. 71). This remark is made in view of the "wavy or minutely undulated lamination, arising apparently, from a contorted or wavy structure in the coarsely crystallized mica, its predominant mineral, which he thought, seemed "to proceed from the interference of innumerable planes of cleavage—or what is the same thing —of crystalline lamination, with the original planes of deposition of the strata."

He remarks a character which possibly might be attributed to remoteness of the upper gneisses from the zone of intense crystalline action:

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*_The Geology of Pennsylvania, Government Survey._ By Henry Darwin Rogers. In two vols. 4to, New York, 1868. The author informs us in the preface that the survey was commenced in 1836; interrupted from failure of appropriations in 1842; revived in 1851 (after sundry failures in attempts to accomplish publication); the field work was concluded in 1855, report rewritten and placed in way of publication under direction of the author. The preface is dated Philadelphia, April, 1858.

"A remarkable feature in the northern or uppermost band of gneiss on the Schuylkill, or those which next adjoin the base of the Primal series, is the possession of a less than usual completeness of crystallization in the constituent minerals, the feldspar more especially, appearing to be less perfectly developed than common, and more in the condition of roundish or lenticular, segregated lumps. In this circumstance, the gneiss here approximates somewhat to the structure of the lowest beds of the Primal series, which are also porphyroidal, but exhibit their metamorphism in a far lower degree" (p. 73).

The prevailing Appalachian dip is not remarked in the gneisses:

"A remarkable feature in the structure of the whole southern gneiss district is the prevalence of a northward dip in the strata. This inclination prevails along the Schuylkill, with very few local and trivial exceptions throughout all the three great subdivisions of the zone of gneiss" (p. 78).

I make one more quotation, setting forth a conception in reference to Appalachian structure, which demonstrates long and thoughtful observation:

"That the wide area of gneiss now under description is undulated in a succession of anticlinal and synclinal waves is obvious to any practiced geological observer who studies its structure with due care. . . The notion of an undulated or folded structure in the gneiss finds corroboration in the parallel arrangement of the hills and valleys; and in the sudden changes in the dip of the strata, wherever we make a transverse section through the region; but it receives its most positive demonstration, when we study the topography and distribution of the gneiss on the western side of the county. There as we have already seen, several long tapering tongues of the gneiss formation project forward towards the W, including between them actual troughs of the Palæozoic rocks, a feature not attributable to any other mode of elevation of the gneiss than that of an undulation of its general floor in the manner of long anticlinal waves" (p. 86). In reference to inverted flexures in the South mountains, see page 94.

JAMES HALL.

1843. In his Final Report on the geology of the Fourth District of New York,* Mr. Hall, like Mr. Mather and Mr. Vanuxem,**

**Geology of New York. Part IV, Comprising the Survey of the Fourth Geological District.* By James Hall, Albany, 1843.

**Vanuxem's chapter on the Taconic system occupies but about one page (pp. 22,23.) The rocks of the system barely entered his district. Unlike Mather, he agreed with Emmons as to the validity of its existence. The following, however, is a curious paragraph:

makes mention of the Taconic system, then recently proposed by Dr. Emmons. But, with Mr. Hall, a mere mention suffices. He says: "II. Taconic System. Represented by the Taconic range of mountains in the eastern part of New York." (p. 17.)

1847. Mr. Hall's attitude toward the Taconic was disclosed in the first volume of the Palæontology of New York* where the trilobites described by Dr. Emmons under the names *Atops trilineatus*, and *Elliptocephalus asaphoides*, as representatives of Taconic life, were described as *Calymene beckii*, an authentic species of the Hudson River group, and *Olenus asaphoides*, presumed also to be of similar age. He says:

"Supposing the existence of a system of strata below the Potsdam sandstone, of which we have no proof, we might fairly infer that the wide interval between the deposition of those strata and the Hudson River group, would give us forms of animal life more widely different than these examples offer" (p. 257, note.)

1859. So far as I have observed, professor Hall had no occasion to assume positions bearing on any questions concerning pre-Silurian rocks, until some [assumed] "Trilobites of the Shales of the Hudson River Group" from northern Vermont, were placed in his hands.† These were described as *Olenus thompsoni, Olenus vermontana and Peltura* (*Olenus*) *holopyga* (pp. 59-62). These fossils, as it appeared, were obtained from the district claimed by Emmons as representing the Taconic system. Though these were not generic types characteristic of the horizon of the Hudson River group, the controlling reason for placing them there, is expressed in the appended note as follows:

"NOTE. In addition to the evidence heretofore possessed regarding the position of the slates containing the trilobites, I have the testimony of Sir W. E. Logan, that the shales of this locality are in the upper part of the Hudson River group, or forming a part of a series of strata which he is inclined to rank as a distinct group, above the Hudson River proper. It would be quite superfluous for me to add one word in support of the opinion of the most able

"It is a convenient receptacle for deposits which belong neither to the Primary nor the New York System; and the mind in England is disposed to one of the kind. since the Cambrian System holds the same position. From [To] the necessity of a connecting link between the Primary and the Secondary classes, which alone existed when Werner rose as a geologist, we owe the Transition class, the fruits of which are the Cambrian System of Mr. Sedgwick, the Silurian of Mr. Murchison, and the Devonian of Mr. Phillips; now merged, with the exception, probably, of a portion of the Cambrian, in the New York System.'

**Palæontology of New York*, Volume I. By James Hall, 1847.

†*Twelfth Annual Report of the N. Y. Regents. Contribution to the Palæontology of N. Y., 1855, '56, '57 and '58.* By James Hall. 1859. Professor Hall has informed us that this report was published previous to Sept. 20, 1859.

stratigraphical geologist of the American continent" (p. 62, note.)

1860. In the Thirteenth Report of the Regents*, professor Hall changed the generic references of the three trilobites just mentioned, establishing for them, two new genera. They are here described (the first with a new figure) under the names *Barrandia thompsoni*, *Barrandia vermontana* and *Bathynotus holopyga.* The technical reasons for these changes are explained. In reference to geological position, he says, in a paragraph at the end:

"The geological horizon of the shales in which these trilobites occur, having been made a matter of discussion among geologists, I shall refer those interested in the subject to the forthcoming report upon the Geology of the State of Vermont, by Professor E. Hitchcock," (p. 119, see anté, p. 99).

1861. This reference of the Georgia trilobites a horizon as high as the Hudson River group, was questioned and somewhat sharply criticised by M. Barrande† in 1860. Professor Hall, accordingly, made a restatement of the reasons which induced him to refer the Georgia trilobites to the Hudson River horizon. The truth of history, not to say justice to professor Hall, demands the quotation of some passages.‡ After stating that Sir William Logan had authorized in an explicit manner, the note appended to his paper in the *XIIth Regents' Report*, he proceeds:

"Later discoveries in the limestones associated with the shales at Quebec leave no longer a doubt, if any could have been entertained before, that the shales of Georgia, Vermont, are in the same relative position [i. e., of Quebec age, instead of Hudson River] and we must regard these three trilobites as belonging to the same fauna with the species enumerated by Sir William Logan as occurring in the Quebec group. Left to palæontological evidence alone, there never could have been a question of the relations of

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**Appendix. Contributions to Palæontology, 1858 and 1859, with additions in 1860.* By James Hall. This report, according to a slip attached to *XIVth Report*, was published before Dec. 17, 1860.

†*Neues Jahrbuch für Geologie und Petrefaktenkunde.* A translation of the letter written under date of Paris, July, 16,1860 to Prof. Bronn is given by M. Marcou, in a memoir entitled "On the Primordial Fauna and the Taconic System, By Joachim Barrande. With additional notes." From the *Proceedings of the Boston Society of Natural History*, vol. vii., Dec., 1860, pp. 369-382. Republished in *Amer. Jour. Sci.*, II., xxxi, pp. 212-15, Mar., 1861. M. Barrande wrote of these fossils: "Their primordial nature cannot admit of the least doubt, when the descriptions are read, accompanied with wood engravings which the large dimensions of these three species render sufficiently exact......All the characters of these three trilobites, as they are recognized and described by J. Hall, are those of the trilobites of the Primordial fauna of Europe. . Such is my profound conviction, and I think any one who has made a serious study of the trilobitic forms, and of their vertical distribution in the oldest formations will be of the same opinion" (pp. 371-372.)

‡*Amer. Jour. Sci.*, II, xxxi, pp. 220-6, March, 1861; *Canad. Naturalist*, vi, 113-20, Apr. 15, 1861; Geol. Vermont, i, 382-6.

these trilobites, which would at once have been referred to the Primordial types of Barrande.

"Sir William Logan yields to the palæontological evidence, and says, 'there must be a break.' He gives up the evidence of structural sequence which he had before investigated, and considered conclusive; and having heretofore [myself], relied upon the opinion of the distinguished geologist of Canada, in regard to a region of country to which my own examinations had not extended, I have nothing left me but to go back to the position sustained by the palæontological evidence." *

He then examines the palæontological evidence, and from a tabular exhibit of Quebec fossils, concludes:

"In the table we find, of previously recognized tribolites of the primordial faunæ, four genera and eight species; two genera before known in the Potsdam sandstone, and seven species; and of *Agnostus*, which is of the first and second faunæ, two species; and one new genus, with nine species."

"These are certainly very curious results; and a modification of our views is still required, to allow four genera and eight species, or, leaving out *Amphion*, three genera and six species of tribolites of the second fauna, to be associated with two genera and five species of tribolites of the primordial fauna, and yet regard the rocks as of primordial origin" (pp. 224). . . .

"In the present discussion, it appears to me necessary to go further, and to inquire in what manner we have obtained our ideas of a primordial or of *any* successive faunæ. I hold that in the study of the fossils themselves, there were no means of such determination prior to the knowledge of the stratigraphical relations of the rocks in which the remains were enclosed. There can be no scientific or systematic palæontology without a stratigraphical basis. Wisely then, and independently of theories, or of observations and conclusions elsewhere, geologists in this country had gone on with their investigations of structural geology. The grand system of Professors W. B. and H. D. Rogers had been wrought out, not only for Pennsylvania and Virginia, but for the whole Appalachian chain, and the results were shown in numerous carefully worked sections. In 1843, '44 and '45, I had myself, several times crossed from the Hudson river to the Green mountains, and found little of importance to conflict with the views expressed by the Professors Rogers in regard to the chain farther south, except in reference to the sandstone of Burlington, and one or two other points, which I then regarded as of minor importance."

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* *Amer. Jour. Sci.*, II, xxxi, 221.

"Sir William Logan had been working in the investigation of the geology of Canada; and better work in physical geology has never been done in any country."

"This, then, was the condition of American geology, and investigators concurred, with little exception, in the sequence based on physical investigations. As I have before said, our earliest determinations of the successive faunæ depend upon the previous stratigraphic determinations. This, I think, is acknowledged by Mr. Barrande himself, when he presents to us as a preliminary work, a section across the centre of Bohemia. With all willingness to accept Mr. Barrande's determination, fortified and sustained as it is, by the exhibition of his magnificent work upon the trilobites of these strata, we had not yet, the means of parallelizing our own formations with those of Bohemia by the fauna there shown. . . . It then became a question for palæontologists to decide whether determinations founded on a physical section, in a disturbed and difficult region of comparatively small extent [i. e. Sir W. E. Logan's on the borders of Canada and Vermont] were to be regarded as paramount to determinations founded on examinations, like those of the Professors Rogers, extending over a distance in the line of strike of five or six hundred miles; and those of Sir William Logan over nearly as great an extent, from Vermont to Gaspe." . . . .

"It is evident that there is an important and perplexing question to be determined. . . For myself, I can say that no previously expressed opinion, nor any 'artificial combinations of stratigraphy previously adopted, by me, shall prevent me from meeting the question fairly and frankly" (pp. 224-5-6).

1862. The new evidences in reference to the age of many of the rocks in the valley of the Hudson, led professor Hall to an abandonment, at least for a time, of the use of the term Hudson River group, for the assemblage of strata next above the Trenton group. In a note at the end of his report on the geology of Wisconsin, he records this changed position.*

"At that time [when the final reports on the geology of New York were in preparation] and at a later period, Dr. Emmons proposed the name Taconic System for a series of rocks lying a considerable distance to the eastward of the Hudson River, and which were, according to the author of that System, below the Potsdam sandstone. An examination of the slaty rocks of the System in some of their typical localities, proved, in the opinion of the writer, that

**Report on the Geological Survey of the State of Wisconsin*, vol. i. Jan. 1862, pp. 47 and 443-5.

they rested upon the Potsdam sandstone; and in tracing the same beds toward the Hudson River, there could be discovered no break or interruption in the strata anywhere to the east of that river. . . At a subsequent period, Dr. Emmons extended the application of the term Taconic System to the rocks of the Hudson River valley, including the area originally regarded as the typical locality of the Hudson River Group. . . Within the last few years, the discussion of the subject has been revived, more particularly from discoveries of fossils in Vermont and Canada, which prove conclusively that these slates are to a great extent, of older date than the Trenton limestone."

"Looking critically at the localities in the Hudson valley which yield the fossils [belonging to the second fauna] we find them of limited, and almost insignificant extent. . . Besides the fossils just mentioned, we know of no others for nearly a hundred miles along the Hudson valley, with the exception of the Graptolites, which have heretofore been referred to the age of the other fossils found in the smaller outliers, or to the second fauna, but which in reality, hold a lower position, and belong to the great mass of the shales below."

"Until recently but one or two other species of known older types of fossils (those of the Primordial fauna) had been discovered in these slates. But within the past few years, the number discovered has been very great. . . We are therefore satisfied. . . that the term Hudson River group cannot properly be extended to . . . the Lorrain shales and the shales and sandstones of Pulaski, etc. . . I have therefore dropped the term Hudson River group in its application to the rocks of Wisconsin which are of the age of the Lorrain shales of New York, and the 'blue limestone' of Ohio." . .

1864. The field examination made in 1864 in company with Sir W. E. Logan, has already been mentioned. *Ante'*, p. — This resulted in the recognition of a wide distribution southward, of rocks belonging to the Quebec and Sillery formations. These identifications were made in the midst of a region which had generally been regarded as underlaid originally by altered strata of Hudson River age.

1877. The conclusions reached in 1861 and 1862, in reference to the age of the mass of rocks along the east side of the Hudson river, were found to be only partially true.* Later investigation showed the existence along both sides of the river, of a body of

*"Note upon the History and Value of the term Hudson River group, in American Geological nomenclature." *Proc. Amer. Assoc.*, Nashville, 1877, pp. 258-65.

slates lying in unquestionable continuity with the Lorrain shales of the Mohawk valley and the northwestern part of the state, and professor Hall therefore reclaimed the term Hudson River group as appropriate. No particular citations of reasons assigned is needed here. Professor Hall however, still recognized the existence of a mass of slates farther east in New York, which contained fossils of the Primordial fauna. These, therefore, still remained, to validate, as far as they could, Dr. Emmons' contention for the existence of a pre-Silurian, fossiliferous system.

SIR WILLIAM LOGAN.

1845. The first record of observations made by Sir William Logan on the range of rocks here under consideration*, speaks of them collectively, as the "Metamorphic Series." But he recognizes a lithological and chronological subdivision.

"To the south of the Mattawa and of the Ottawa in its continuation after the junction of the two streams, important beds of crystalline limestone become interstratified with the syenitic gneiss,and their presence constitutes so marked a character that it appears expedient to consider the mass to which they belong as a separate group of metamorphic strata, supposed, from their geographical position and general attitude, to overlie the previous rock conformably. The limestone beds appear to be fewer at the bottom than at the top of the group, but whether few or many, they are always separated by beds of gneiss which in no way differ in constituent quality or diversity of arrangement from the gneiss lower down, except in regard to the presence of accidental minerals, the most common of which are garnets," (pp. 41, 42).

The facts stated would seem to afford but slender ground for the recognition of two "groups."

But this grouping is traced over an extent of sixty-three miles, when the result of his observations is expressed in the following arrangement:

4. Fossiliferous limestone [with Niagara fossils.]
3. Greenish sandstones [of undetermined relations.]
2. Chloritic slates and conglomerates [subsequently Huronian.]
1. Gneiss (p. 67.)

1846. The series on the north shore of lake Superior is further described in the report of the following year†. The order of succession determined is given below:

5. Sandstones, limestones, indurated marls and conglomerates, interstratified with trap.

Report of Progress of the Canada Geological Survey for 1845-6, pp. 40-45.
†*Report of progress for 1846-7*, pp. 8-17.

4. Bluish slates or shales, interstratified with trap. [Huronian Animike.)
3. Chloritic and partially talcose and conglomerate slates.
2. Gneiss.
1. Granite and syenite.

On these Mr. Logan makes the following remarks:

"The rock at the base of the series is a granite, frequently passing into a syenite by the addition of hornblende; but the hornblende does not appear to be often present wholly without the mica. . . This granite appears to pass gradually into a gneiss, which seems to participate as often in a syenitic as a granitic quality. . . The gneiss is succeeded by [3] slates of a general exterior dark green color, often dark gray in fresh fractures, which at the base appear occasionally to be *interstratified* with beds of a feldspathic quality, of the reddish color belonging to the subjacent granite and gneiss. . . Some of the beds have the quality of a greenstone, others, that of a mica slate, and a few present the character of quartz rock. Rising in the series, these become [4] interstratified with beds of a slaty character, holding a sufficient number of pebbles of various kinds to constitute conglomerates. The pebbles seem to be of various qualities, but apparently all derived from hypogene rocks. . . [Ogishke conglomerate?] "The formations which succeed [5] rest *unconformably* upon those already mentioned. The base of the lower one where seen [in Thunder Bay] in contact with the subjacent green slates presents conglomerate beds, probably of no great thickness, composed of quartz pebbles chiefly, with a few of red jasper, and some of slate in a green arenaceous matrix, consisting of the same materials in a finer condition." [Afterward "slate conglomerate."]

The [5] sandstones, limestones, indurated marls and conglomerates, are said to be crowned by an enormous amount of volcanic overflow.

In the light of our own studies, it becomes easy to recognize in No 3 the rocks of the Keewatin iron-bearing series, represented on the south shore by the Marquette iron-bearing series; in No. 4, the chloritic diabase slates of the Thessalon valley, and in No. 5, the "slate conglomerate" and quartzites and Trap-rocks of the same regions, and the Animike slates of northeastern Minnesota,* while the crowning overflow is the great gabbro sheet so widely spread in northern Minnesota.

*Erroneously supposed by Whitney and Wadsworth to represent the Cupriferous formation of the south shore (*Azoic Rocks*, p. 334). As the Cupriferous is with them of Potsdam age, we should have an astonishing equivalency between the Potsdam sandstone and the Animike black slates.

It is important to keep in mind the early recognition of an unconformity between the two series of schists Nos. 3 and 4, and the existence of quartzose pebbles in the bluish slates,* as in the blackish slates of the Thessalon valley.

1847. In order to describe the grounds of director Logan's determinations respecting the geology of the region north of lake Huron it is necessary to make a quotation from Mr. Murray's report of a survey in 1847.†

"The older groups observed, consist firstly, of a metamorphic series composed of granitic and syenitic rocks in the forms of gneiss, mica slate and hornblende slate; and secondly, of a stratified series, composed of quartz rock or sandstones, conglomerates, shales and limestones. . . . On a cluster of small islands, . . . granite was found breaking through the quartz rock. The color of the rock [which rock ?] was red. On one of the islands, quartz rock beds on opposite sides of the granite, were observed to dip in opposite directions, north on the north side, and south on the south side, at an angle of 78° or 80°; and in another of the islands, the quartz rock and granite were seen in juxtaposition, the former reclining on the latter. In this case the quartz was traversed by several trap dikes running slightly oblique to the strike, while granitic veins ran transversely through the whole, and were continued through the main body or nucleus of the granite, the one granite being distinguishable from the other notwithstanding the red color of both, by the finer texture of the veins" (pp. 112, 113).

This is the earliest description of a portion of the rocks in what was to become "the original Huronian region." An examination of the statements made by Mr. Murray justifies the conclusion that the rocks described correspond to the 'upper group' found by Logan on the north shore of lake Superior. But it will be seen that Logan parallelizes them with the *metamorphic* series of the north shore, without paying due regard to the unconformity which he has described running between the upper and lower

* These are described as *black* argillaceous slates by Mr. Alexander Murray (same report, pp. 51-3) After noticing the two groups and the structurally *conformable* passage of the lower into the bottom gneisses, he says of the upper (black argillaceous slates) "The base of this formation . . . was observed on the Kaministiquia, near the Grand Falls. Its immediate junction with the rock on which it reposes was concealed from view, but appears to be indicated by the position of a small lake or pond occurring just below the second portage, and the marshy ravines which run from it in the direction of the strike on each side. The slates visibly reach to within a short distance of the pond, probably brought into place against the syenite by a dislocation.

† Murray, *Report of Progress for 1847-8.*

groups. Thus, in reference to the second series of Mr. Murray, he writes in 1848 : *

"The series of rocks occupying this country form the connecting link between lakes Huron and Superior to the vicinity of Shebawenahning, a distance of 120 miles, with a breadth in some places of ten, and in others exceeding twenty miles, and it appears to me, must be taken as belonging to one formation; on the west it seems to repose on the granite which was represented in my report on lake Superior as running to east of Gros Cap, north of Sault Ste. Marie ; on the east, the same supporting granite was observed by Mr. Murray, north of La Cloche, between three and four miles in a straight line up the Rivière au Sable, . . . and again about an equal distance up another and parallel tributary, . . . in both cases, about ten miles from the coast. . . . In respect to the geological age of the formation, the evidence afforded by the facts collected last year by Mr. Murray, . . . is clear, satisfactory, and indisputably conclusive. . . . The chief difference in the copper-bearing rocks of lakes Huron and Superior seems to lie in the great amount of amygdaloidal trap present among the latter, and of white quartz rock or sandstone among the former. But on the Canadian side of lake Superior, there are some considerable areas, in which important masses of interstratified greenstone exist without amygdaloid, [this is the 'upper group'] while white sandstones are present in others, as on the south side of Thunder Bay, though not in the same state of vitrification as those of Huron. But notwithstanding these differences, there are such strong points of resemblance in the interstratification of igneous rocks, and the general mineralized condition of the whole, as to render their positive approximate equivalence highly probable, if not absolutely certain ; and the conclusive evidence given of the age of the Huron, would thus appear to settle that of the lake Superior rocks, in the position given to them by Dr. Houghton, the late state geologist of Michigan, as beneath the lowest known fossiliferous deposits, a position which, as will be seen by a reference to the Report of Progress I had the honor to submit to your Excellency, in 1846, appeared to me to derive some support from evidences on the Canadian side of lake Superior itself."

The positive error embodied in the foregoing paragraph is the attempt to parallelize the Huron rocks with a series of Superior rocks which consists of two groups, and then having shown the parellelism with the higher group, the drawing of inferences touching a

* *Report on the north shore of Lake Huron*, Dec. 29, 1848, pp. 8, 9, 19, 20.

third geological region which are valid only in reference to the lower Superior group.

The foregoing citation from the report of 1848, was embodied in a communication made by director Logan to the British Association in 1851.* But in place of the last part of the last sentence, we find the following: "and in this sequence, those [rocks] of Lake Huron, if not those of Superior, would appear to be contemporaneous with the Cambrian series of the British Isles." In the next paragraph, he says the Lower Silurian, on the lower St. Lawrence, "appears to rest upon gneissoid rocks, without the intervention of the Cambrian" (*Amer. Jour. Sci.*, l. c., p. 226;) and in the next, he uses the phrase, "Cambrian formation of Lakes Huron and Superior" (p. 227), and the same again on the next page. It is clear then, that in 1851, Sir William Logan considered the rocks on the north shore of lake Huron as equivalent to the Cambrian of Sedgwick.

1848. We must again cite from Murray, as it appears that director Logan's judgments were largely based on assistant Murray's facts. In the report for 1848–9, after describing the country along the Spanish river, he says:

"The geological formations met with in the region thus described, may be arranged in two groups, one of which appears to be nearly allied to, and the other identical with, the older rocks of which mention was made in my report of 1847–8. They are

2. Quartz rock group.
1. Granitic or Metamorphic group.

Mr. Murray, in describing the lower group, mentions only granitoid rocks. He says: "The constituent minerals were usually those of granite or syenite, or a mixture of both. . . A gneissoid structure was observed on one or two occasions, . . but obscure and ill defined." Speaking of the "Quartz rock group," he says:

"The rocks of this group, where they came under our observation, like those examined the previous season, were found to be partly of aqueous and partly of igneous origin." After describing the quartzose members, he speaks of the slate. "The slates were gray, green or blackish in color, and were usually more or less silicious, and frequently very micaceous. . . The more purely argillaceous portions of the slate were generally *black* or of a *very dark brownish* tinge, and in these a very symmetrical jointed structure, dividing the rock into rhombohedral forms of considerable regularity, was frequently recognized. The slates were very

**Rep. Brit. Assoc. Adv. Sci.* 1851. Trans. Secs. 59-62 *Amer. Jour. Sci.* II, xiv, 224-229. See also *Bull. Soc. géol. de France*, 1849-50, (2), vii, 207-209.

often observed to pass into a conglomerate, holding pebbles of granite and syenite chiefly, varying in diameter from an eighth of an inch to a foot, and imbedded in a *black argillaceous matrix*" (p. 37.)

No one who has seen Logan's slate conglomerates in the valley of the Thessalon, can fail to recognize the identity of the argillaceous slates described by Mr. Murray.

1849. In the report for 1849–50, director Logan describes the geology about Bay St. Paul and Murray bay. He classifies the rocks as follows:

4. Bituminous limestone (Trenton.)
3. Calciferous sandrock.
2. White quartz rock (Potsdam sandstone.)
1. Metamorphic group (p. 8.)

Referring to the "Metamorphic group," he states that the prevailing rock of the country is gneiss, sometimes of a granitic and sometimes of a syenitic character. After careful local details, he says:

"The gneiss of this district belongs to that metamorphic group of rocks, which in previous reports has been described as existing on the Ottawa, and as traceable thence . . to Cape Tourmente below Quebec. . . None of the highly crystalline limestones which on the Ottawa are so marked a feature of the group, were observed in the region under attention."

This fact gives support to the suggestion of Whitney and Wadsworth that the Laurentian limestones may be mere segregations, instead of extensive strata.

A white, translucent, slaty quartz rock, rendered cleavable by the presence of silvery mica, but seen only at three points, directly overlies the gneiss. "There appears to be little doubt that this rock is equivalent to the Potsdam sandstone of New York" (p. 10.)

1851. This year director Logan and assistant Murray examined different portions of the district between the Ottawa and the St. Lawrence. Mr. Logan describes the Potsdam sandstone as reposing unconformably on the "Metamorphic or gneissoid group" (p. 6.) The character of this "group" may be learned from Mr. Murray's description of the geology of Rigaud mountain (*Report of Progress*, p. 63.) After speaking of the occurrence of gneisses, he says:

"These beds are *interstratified* with others of a different character; one set is composed of small cleavable forms of black hornblende and grains of translucent, yellowish-white feldspar, weathering opaque-white, and crystals of brown mica. Another consists of grayish-green cleavable pyroxene, with individuals of greenish feldspar weathering white, and largely disseminated grains of magnetic iron; and a third consists of translucent albite, with black hornblende and magnetic iron ore disseminated, alternating with micaceous layers. All these beds are intersected by transverse dykes, some of which are fine-grained, grayish-black trap, probably a greenstone with disseminated grains of calc-spar, while others are porphyritic, having a fine grained blackish-green base, with individuals of greenish white feldspar" (pp. 63-64.)

This passage sounds very unlike the descriptions of the rocks about Spanish and Thessalon rivers. But these are the rocks which in the Seigniory of Rigaud, rest directly upon the gneisses. It is further stated (pp. 60, 65,) that at the base of 71 feet of sandstone, on Bluff island in Charleston lake, is a "red talco-quartzose rock of the Metamorphic series." No such rock is described in the region north of lake Huron. There is reason to suppose another group of rocks rests in this region in a position between the gneiss and the "Huron rocks."

Of the deeper gneisses Mr. Murray supplies some interesting information:

"Near Furnace Falls, on the second lot of the eighth concession of Landsdowne, there is a considerable display of crystalline limestone, holding as usual, spangles of graphite and mica, with grains of quartz. . . Crystalline limestones are also, extensively exhibited in the neighborhood of Beverly, township of Bastard, and Newboro' in south Crosby. Their color is usually white, but sometimes grayish-white, or white with gray bars or stripes. Small scales of graphite are invariably disseminated through the rock, with serpentine, mica and iron pyrites. . . The texture of the limestones is usually coarse. . . Nodular masses of vitreous white quartz, surrounded with thin layers of brown mica, and both enclosed in foliated green pyroxene, are met with in some of the beds. . . On the twenty-fourth lot of the tenth concession of Bastard, there is an unmistakable bed of *conglomerate*, interstratified between two beds of highly crystalline limestone, showing the sedimentary origin of the Metamorphic series. The following is a condensed statement of the section given (p. 62.)

7. Crystalline limestone, white, coarse-grained, 6 ft.
6. Crystalline limestone, fine, very hard, bluish-gray, 4in.
5. Calcareous sandstone, fine-grained, 2 in.
4. Coarse conglomerate. The pebbles are flat and lie on their sides, etc., 1ft. 6in.
3. A calcareous aggregate of quartz, with feldspar, calc spar and scales of graphite, 2in.

2. An aggregate of colorless, translucent quartz, with feldspar and patches of greenish, chloritic limestone, with brown mica, 4in.
1. Pure white, highly crystalline, coarse limestone, 5ft.

1852. Director Logan returns to an exposition of the rocks north of lake Huron,* and states:

"On Lake Huron, the Lower Silurian group rests unconformably upon a silicious series, with only one known band of limestone, about 150 feet thick, with leaves of chert in abundance, but as yet, without discovered fossils. This series is supposed to be of the Cambrian epoch. It comprehends the Copper-bearing rocks of that district, and with its igneous, interstratified masses, has a thickness of at least 10,000 feet. The gneissoid group, of which mention is made, is probably still older than this. Its conditions appear to me to make it reasonable to suppose that it consists of aqueous deposits in an altered state."

1854. The first announcement of the term Laurentian, as the designation of a series of rocks, was made in 1854.†

"The name which has been given in previous reports to the rocks underlying the fossiliferous limestones in this part of Canada, is the "Metamorphic series;" but inasmuch as this is applicable to any series of rocks in an altered condition, and might occasion confusion, it has been considered expedient to apply to them for the future, the more distinctive appellation of the *Laurentian series*,‡ a name founded on that given by Mr Garneau, to the chain of hills which they compose."

In the same report, Mr. Murray, writing of the region between lake Ontario and lake Simcoe, supplies a general description of the Laurentian series, in these words:

"They consist of masses of micaceous and hornblendic gneiss, and masses of crystalline limestone interstratified by gneiss. In

**Quar. Jour. Geol. Soc.*, viii, 210, 1852.

†*Report of Progress, Geolog. Surv. Canada, for the year 1852-3*, Quebec, 1854, p. 8.

‡The term "Laurentian" had already been applied, in 1851, by Edward Desor, to the fossiliferous marine Drift of the valley of the St. Lawrence river (*Proc. Boston Soc. Nat. Hist.*, Feb. 19 and March 5, 1851, vol. IV, pp. 29, 33.) It was also published in the *Bulletin of the Geological Society of France* in the same year and in 1852; in the Neues Jahrbuch for 1853; and in Thompson's *Natural History of Vermont*, in 1853.

The term "Algonquin terrane" was also preoccupied by Desor, in 1851, as the designation of the fresh-water deposits about the Great Lakes, to which C. H. Hitchcock and J. D. Dana have since applied the term Champlain. The name "Algonkian" has been (in 1889) proposed by C. D. Walcott, for all the sub-Cambrian deposits down to the top of the crystalline schists. Thus a notable parallelism exists in the fortunes of the two terms proposed by Desor, for two distinct members of the Quaternary.

For a history of the use of the term "Laurentian as applied to a Quaternary terrane," see Joseph F. James in *American Geologist*, Jan. 1890. pp. 29-35; also C. H. Hitchcock, in *American Geologist*, April 1890, and Jules Marcou, in *American Geologist*, vol. VI, p. 64.

the great masses of gneiss, the prevailing color appears to be reddish, but they are frequently striped with interstratified bands of gray, the reddish part taking its general aspect from the reddish feldspar which is the principal constituent, while the gray is chiefly made up of small grains of white quartz and feldspar, with small scales of black mica, and occasionally grains of black hornblende. . . Beds also occur of which almost the only constituent is white quartz, and these often alternate with thin layers of yellowish white feldspar," (pp. 81, 82).

Various beds of crystalline magnesian limestone are described: —One on Eel lake 30 feet thick, and several other exposures on the same lake (pp. 83, 84); another on Long lake, seventh lot of ninth concession (with little magnesia), with apatite, silvery mica and graphite, and a few grains of rose-colored quartz, and some green serpentine; another below this, on Gold lake, with abundant grains and nodules of greenish serpentine; another, still lower, of white dolomite, with pinkish streaks and spots, with grains of quartz and serpentine (p. 84). Many other exposures are described, of similar general character. "Southwest from the Gold Lake limestone, in the continuation of the general strike, an exposure was met with on the fourth lot of the eighth concession. . . From the vicinity of this exposure, crystalline limestone is traceable, emerging from beneath the fossiliferous formations for a mile and a half" (p. 85).

If then these limestones are "low" in the gneissic series, an occurrence so near the fossiliferous limestones would imply the absence of a large part of the gneissic and the whole of the schistic rocks.

At an exposure on Birch lake, Mr. Murray measured a section, of which the following is a synopsis: (p. 89.)

11.	Mica slate, fine, with bands of coarse, disintegrating limestome	86ft.
10.	Limestone, coarse, disintegrating	40
9.	Feldspathic quartz rock and coarse disintegrating limestone	50
8.	Red, ferruginous mass, of brecciated appearance [See also p. 94]	10
7	Crystalline limestone, coarse, disintegrating	30
6.	Crystalline limestone, coarse, with graphite nodules and angular fragments of quartz	100
5.	Concealed from view	231
4.	Gneiss, mostly quartz, some black and brown mica and abundant garnets [Not very good gneiss]	260

3.	White quartz and fine-grained feldspar alternating.	130
2.	Supposed to be chiefly mica schist................	300
1.	Gneiss, red and gray, thin bedded, with layers of mica schist........................	132
		1369

1857. The reports of the Canadian survey for 1853, '54, '55, '56 were not printed until 1857.* In Murray's reports for 1853 and 1854, he describes the country between Georgian bay and the Ottawa river. "The Laurentian series" occupies most of the country. He speaks of *gneiss in alternation with mica slate.* Some highly garnetiferous portions are mostly an aggregation of granular quartz. He speaks also, of a black rock composed chiefly of hornblende, with some black mica (pp. 89, 90.) A fine grained red rock, supposed to be intrusive (p. 90) is spoken of, and beds of limestone are particularly located (pp. 91, 92, 93.) Bands of limestone are found about lake Nipissing (pp. 121, 122, 123.) The "Laurentian series" of lake Nipissing is further described in Murray's reports for 1855 and 1856 (Rep. 1857, pp. 140-3.)

"Among the boulders on lake Nipissing" says Mr. Murray, at the end of the report for 1855—printed in 1857, "many were observed to be of a slate conglomerate, and they were frequently of very great size; in their aspect and general character, these have a very strong resemblance to the slate conglomerate of the *Huronian series,*† from which, in all probability, they are derived" (p. 125.) In the report for 1856, he speaks of the bowlders of metamorphic rocks as derived from the Laurentian and Huronian formations on the north shore of lake Huron (p. 134.)

In reference to the red rock first mentioned in the report for 1853, (p. 90,) he says:

"At Grand Recollet Fall, in the north channel of the French River, and in the south channel about two miles southeast from them, the rock is of a brick red color, without any distinguishable lines or layers of stratification. It was supposed to be an intrusive syenite, and with a general breadth of from one to two miles, its course appeared to be N. N. W. and S. S. E., (141, 142.)

*The volume printed in 1857, of 494 pages, contains reports of Murray and Hunt for 1853, 1854, 1855, and 1856, and reports of Mr. Billings and Mr. Richardson for 1856.

†The term "Huronian" is evidently employed in this place, as a geographical designation, rather than the name of a well-considered historical assemblage of rocks occurring in the Huronian area and elsewhere. Systemically, these rocks were understood by Sir William Logan, as he tells us, to belong to the Cambrian (See *ante*, p. 116, 1852, in *Rep.* for 1851.) It will be remembered also, that Emmons had declared that they fall within the limits of the Taconic (See *ante*, p. 82, 1860, p. 18;) and it does not appear that the insistance upon the use of term Huronian has been formally defended—a lack of any attempt at justification which is explained only by the apparent assumption that the claims of Taconic were too preposterous to merit consideration.

Director Logan, in a note, suggests the resemblance of this red rock to some of the harder kinds of the *laterite* rock of the East Indies. He cites Dr. Clarke, as concluding, in 1838, that it results from decomposed syenite or hornblendic gneiss. "The Canadian rock," Mr. Logan adds, "seems to be a syenite in an incipient state of decomposition."

In his report for 1856, dated 1st March, 1857, Mr. Murray, speaking of the "distribution of the rock formations" between lake Nipissing and lake Huron, says:

"The rocks of the region explored during the season, embrace two of the oldest recognized geological formations, the Laurentian and Huronian; the rocks of the latter and more recent of which, have been observed to pass unconformably below the lowest of the fossiliferous strata of the Silurian system. The contorted gneiss of the Laurentian series, with its associated micaceous and hornblendic schists, spreads over the country to the south and east, while the slates, conglomerates, limestone, quartzyte and greenstone of the Huronian, occupy the north and western part" (p. 168). The boundary between the two coincides approximately with the White Fish river. The *immediate contact was nowhere distinctly seen* (168, 171). In passing "from the lower to the higher formation, a mass of rather coarse grained greenstone was generally met with." Mr. Murray gives, with many doubts, an approximate section of the Huronian series (p. 172), from which the following statement (omitting interpolated trap beds) is condensed:

6. Quartzyte, white and very pale sea-green, with beds of quartz conglomerate, the pebbles generally white opaque quartz, but sometimes red and green jasper.
5. Green, silicious, chloritic slates, and bands of quartzyte.
4. Slate conglomerate.
3. A band of limestone, much disturbed, often brecciated, pale whitish gray to dark blue.
2. Slate conglomerate, matrix always greenish, sometimes slaty, sometimes resembling a massive, fine grained greenstone; with many pebbles of white and red syenite, and occasional rounded masses of green, brown and red jasper.
1. Slate, fine grained, green, silicious with thin bands of green quartzyte; also, fine grained slates, sometimes greenish, often bluish or black, weathering very black; occasionally some layers of a reddish color.

The total thickness is supposed to be about 10,000 feet (p. 186).

The dips of the rocks of this series are generally under 45°, but they locally vary from horizontal to 90°. The strikes vary from east northeast to west northwest. It appears to be a region of general disturbance. "An immense mass of magnetic trap" was found on White Fish lake. This is about midway between lake Wahnapitæ and island La Cloche in lake Huron, this, according to Hunt's analysis, contains "magnetic iron ore," magnetic iron pyrites" and "titaniferous iron." These facts remind one of the titaniferous and magnetic gabbro of northeastern Minnesota. Limestones are seen on the shore of lake Panache (p. 183). The eastern extremity of the La Cloche mountains is in a white or greenish quartzyte (p. 185).

Director Logan's report dated 3d March, 1857, after summarizing the work of Mr. Murray for the last five years, proceeds to trace the limestone beds of the "Laurentian Formation" in the neighborhood of Grenville and the Calumet river.

In a paper read before the American Association, in August, 1857,* by Sir William E. Logan "On the Division of the Azoic Rocks of Canada, into Huronian and Laurentian," he speaks of them confidently as "a series of very ancient sedimentary deposits in an altered condition." He refers to his suggestion of 1845, to separate the purely gneissoid portion from the portion consisting of interstratified gneisses and limestones, but says the evidence does not permit him to decide certainly which division is most ancient.

He next refers to what was published in the report of 1845, relative to the rocks on lake Temiscaming, consisting of silicious slates and slate conglomerates, overlaid by pale sea-green or slightly greenish-white sandstone, with quartzose conglomerates. The slate conglomerates are described as holding pebbles and bowlders (sometimes a foot in diameter) derived from the subjacent gneiss, the bowlders displaying red feldspar, translucent quartz, green hornblende and black mica, arranged in parallel layers which present directions according with the attitude in which the bowlders were accidentally inclosed. From this it is evident that the slate conglomerate was not deposited until the subjacent formation had been converted into gneiss, and very probably greatly disturbed; for while the dip of the gneiss, up to the immediate vicinity of the slate conglomerate, was usually at high angles, that of the latter did not exceed nine degrees, and the sandstone above it was nearly horizontal."

"In the Report transmitted to the Canadian Government in 1848, on the north shore of Lake Huron, similar rocks are described as

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* *Proc. Amer. Assoc. Adv. Sci.*, 1857, II, pp. 44-47.

constituting the group which is rendered of such economic importance from its association with copper lodes. This group consists of the same silicious slate and slate conglomerates, holding pebbles of syenite instead of gneiss; similar sandstones [quartzites?] sometimes showing ripple marks, some of the sandstones [quartzites?] pale-red green, and similar quartzose conglomerates, in which blood-red jasper pebbles become largely mingled with those of white quartz, and in great mountain masses predominate over them. But the series is here much intersected and interstratified with greenstone trap, which was not observed on Lake Temiscaming. These rocks are traced along the north shore of Lake Huron from the vicinity of the Sault Ste Marie, for 120 miles east." Sir William Logan continues, and indicates the existence of the same formation northeastward 130 miles farther, and as far as the Sturgeon river. The general bearing is northeast, and the dip appears to be almost northwest.

It would be erroneous to suppose that director Logan intended, in the foregoing citation, to say that the gneiss is *immediately* "subjacent" to the slate conglomerate containing gneissic pebbles. No contact between the slate conglomerate and the subjacent gneiss had been reported and it was impossible to affirm that the formation here described was chronologically successive to the gneiss.

"The group on Lake Huron," he continues, "we have computed to be about ten thousand feet thick, and from its volume, its distinct lithological character, its clearly marked date posterior to the gneiss, and its economic importance as a copper-bearing formation, it appears to me to require a distinct appellation, and a separate color on the map. Indeed, the investigation of Canadian geology could not be conveniently carried on without it. We have, in consequence, given to the series, the title of *Huronian.*"

"A distinctive name being given to this portion of the Azoic rock, renders it necessary to apply one to the remaining portion. The only local one that would be appropriate in Canada is that derived from the Laurentide range of Mountains, which are composed of it from Lake Huron to Labrador. We have therefore designated it as the *Laurentian* series.*

Thus a new meaning was given to the term "Laurentian series," which, since 1854, had included all the Azoic rocks.

At the same meeting of the American Association, Sir William Logan read a paper, "On the probable subdivision of the Lauren-

*See also. *Canadian Journal*, 1857, ii, 439-442; *Canadian Naturalist and Geologist*, 1857, ii, 255-258.

tian series of rocks in Canada."* He described two beds of limestone which he had traced in the township of Grenville, on the Ottawa, running N. N. E., with indications that they belong to opposite sides of an overturned synclinal, with anticlinals of gneiss and quartz running parallel on the north and the south. A feature of these and other outcrops of limestone "is the occurrence immediately near the limestones, of immense masses of lime-feldspar. North of the Argenteuil band, eight miles examined across the stratification, consist almost entirely of it, in the form of Labradorite. . . Lime-feldspar is abundant at St. Jerome, and its stratified character is conspicuously displayed—the beds running parallel with the limestone. Mr. Hunt has traced a band of crystalline limestone for eleven miles, running diagonally across the township of Rawdon, in a north bearing. On the west side of this, lime-feldspar forms the great bulk of the rock exposures for twelve miles across the measures, and shows a well marked stratification."

"In Chateau Richer, below Quebec, a band of limestone occurs about a mile from the fossiliferous deposits, and to the northwest of it, lime feldspars present a breadth of eight miles. On an island near Parry's Sound, on Lake Huron, Dr. Bigsby observed the occurrence, *in situ*, of the opalescent variety of Labradorite, and the name of the mineral reminds us of the existence of the rock beyond the eastern end of the Province. It thus appears probable that a range of the rock will be found winding irregularly from one end of the Province to the other, of sufficient importance to authorize its representation by a distinct color on the map, and a distinct designation in geological nomenclature." †

1860. In a letter to M. Barrande, under date of December 31, 1860,‡ Sir William Logan gives an exposition of the fauna of the Quebec group. Toward the end, he notes some recent observations which led him to qualify previous opinions in reference to the age of the Lake Superior sandstone:

"Mr. Murray has this season ascertained that the lowest rock that is well characterized by its fossils, in the neighborhood of Sault Ste Marie, near Lake Superior, really belongs to the Birdseye and Black River group, and that it rests on the sandstone of Ste Marie and Lacloche, the fossiliferous beds at the latter place being

Proc. Amer. Assoc., 1857, Pt. II, 47-51; *Canadian Journal* 1858, II, iii, 1-5; *Canad. Natur.* 1857, ii, 270-274.

†Dr. J. J. Bigsby, nevertheless, has recorded the opinion that the Huronian and Laurentian systems are intimately related in lithological character and conformable position. The reference being especially to the north shore of lake Superior (*Quar. Jour. Geol. Soc.*. 1863, xix, 36-52).

‡*Canadian Naturalist and Geologist*, v. 472-7.

tinged with the red color of the sandstone immediately below them. These underlying Lake Superior rocks may thus be Calciferous and Potsdam, and may be equivalent to the Quebec group and the black colored shales beneath. The Lake Superior group is the upper Copper-bearing series of that region [consisting of 3. Potsdam; 2. Cupriferous; 1. "Slate conglomerates" etc., of lake Huron], and rests unconformably upon the lower Copper-bearing series, which is the Huronian system [as identified about Lake Superior] . . . Professor Emmons has long maintained, on evidence that has been much disputed, that rocks in Vermont, which in June, 1859, I for the first time saw and recognized as equivalent to the magnesian part of the Quebec group, are older than the Birdseye formation; the fossils which have this year been obtained at Quebec, pretty clearly demonstrate that in this he is right."*

1863. No other record on the subject of pre-Silurian rocks appears to have been made by Sir William Logan until the publication of the Geology of Canada, in 1863. This convenient and copious synopsis of Canadian geology, has subsequently been cited for authority, instead of the original reports, and in consequence, geologists have fallen into some misunderstandings."†

"The rocks which compose the Laurentian mountains" writes Sir William Logan, "were shown by the Geological Survey, in 1846, to consist of a series of metamorphic, sedimentary strata underlying the fossiliferous rocks of the province. . . . They are altered to a highly crystalline condition, and are composed of highly feldspathic rocks, interstratified with important masses of limestone and quartzite. Great vertical thicknesses of the series are composed of gneiss containing chiefly orthoclase or potash feldspar, while other great portions are destitute of quartz, and composed chiefly of a lime-soda feldspar, varying in composition from andesine to anorthite, and associated with pyroxene or hypersthene. This rock we shall designate by the name of *anorthosite*."

It can hardly be said that the survey established the conclusion that these rocks were sedimentary in origin; but it pointed out

* This remarkable admission is alluded to by M. Barrande in these words "Terms so clear and possitive need no commentary. It is a formal recognition by Sir W. Logan of the Taconic system at the base of the lower Silurian. Professor Emmons could not wish the assent of a more respectable authority, which cannot fail to secure the adhesion of all American geologists ("Documens anciens et nouveaux sur la faune primordiale et le système Taconique en Amérique, Bull. Soc. géol. de France, Seance, de Fev. 4, 1861. p. 320), Sir William, nevertheless, said only that the shales and limestones of Quebec and Georgia are *subordinate to the Potsdam*—a formation which Dr. Emmons never claimed, though as we have seen, he consented to its inclusion in the Taconic.

† *Report of Progress from its Commencement to 1863.* Illustrated by 498 wood cuts in the text, and accompanied by an atlas of maps and sections. Montreal, 1863, 8-vo, pp. xxvii x 983.

frequently, the evidences of such an origin, and certainly caused it to appear probable. The anorthosite rock referred to above includes the belt of Labradorite described in 1857, which was made the ground of an "Upper Laurentian" or "Labradorian" division. Of this division nothing is said in the general report of 1863. Speaking of the orthoclase gneiss, the writer says :

"A great portion of the rock is fine grained, and the constituent minerals are arranged in parallel layers ; no one constituent predominates in any layer, to the exclusion of others ; but even in their subordinate arrangement, there is an observable tendency to parallelism. . . . There is a never-failing constancy in respect to their parallelism which, however, though never absent, is sometimes obscure." . . . Coarse-grained beds of the character designated "granitoid gneiss," "might, on first inspection, be mistaken for igneous, instead of altered sedimentary masses. Upon a careful study of any such mass, however, it will be perceived that this reticulated structure is accompanied by an obscure arrangement of the meshes of the net-work into parallel lines which will be found conformable with the more distinctly banded portion of the strata" (p. 23).

"The greatest masses appear to be formed of the coarse-grained porphyroidal gneiss above described. These rise into the highest ridges and peaks of the orthoclase region, and generally constitute the main body of rock separating one important band of limestone from another. . . . The quartz occasionally presents masses of considerable volume, two of which, nearly pure, occur in the district of the Rouge, a tributary of the Ottawa, one 400, and the other 600 feet thick. The hornblende often forms a massive rock; a band of it in Blythfield has a thickness of 200 feet. Mica, associated with hornblende and with quartz, characterizes great thicknesses of hornblende and micaceous schists."

"Though there does not appear to be any special order in which the masses succeed one another, beds of hornblende rock, and hornblendic schist seem often to be more abundant near the interstratified bands of limestone than elsewhere, and in the same neighborhood, there usually occurs a more frequent repetition of beds of quartzite than in other parts. Near the limestones, pyroxene, which in other parts does not appear to be very abundantly disseminated, is occasionally met with, forming massive beds" (p. 24).

The writer describes the distribution of garnets in the gneiss, and of its passage, in one instance, into garnetiferous quartzite. The masses of limestone are described, sometimes becoming interstratified dolomytes. Serpentine is found associated with both. Pyrallolite, or rensselaerite often accompanies limestone; and pyroxene and hornblende are sometimes found disseminated in grains or crystals. Tremolite forms beds in it. Mica and graphite are both generally present. Pyrites is more abundant. Other minerals are chondrodite, apatite, fluorite and oxides of iron. The gneiss is sometimes greatly contorted, but the beds of associated limestone, even when very thin, are conformable with the beds of gneiss, and parallel with those bands and streaks with which they are marked (p. 27). One instance has been noted "where the limestone of a bed marked with grains of serpentine, appeared to have an uninterrupted connection with rock of an identical character filling up a crack or fault in the gneiss, at right angles to the general direction of the strata" (p. 28).

In a section measured at the High Falls of the Madawaska, a tributary to the Ottawa, here presented as an average section, there are 48 alternations of beds, in a total thickness of 1351 feet. In these, limestones occur six times, giving an aggregate thickness of 46 feet; quartzyte occurs once, in a bed ten feet thick; and "schistose gneiss" occurs five times, giving an aggregate thickness of 116 feet. At a higher position in the series, is said to be a bed of limestone 100 feet thick. At the Chenaux, there is more limestone than gneiss—there being a thickness of over 400 feet, of which not one-fifth is intercalated gneiss; while in Clarendon, similar rocks reveal "a thickness of 4000 feet, about two-thirds of which consists of crystalline limestone" (p. 31).

Another phenomenon of collateral interest, is thus pointed out:

"Notwithstanding the general highly crystalline condition of the Laurentian rocks, beds of an unmistakably *conglomerate* character are occasionally met with among them. . . . On the twenty-fourth lot of the tenth range of Bastard, a bed of conglomerate is interstratified between two beds of limestone. The dip of the strata at the spot is 30°, N. 50° E." The following is a condensed section:

	Feet.	Inches.
7. Limestone, white, coarse........................	6	
6. Limestone, arenaceous, fine, very hard............		4
5. Sandstone, calcareous, fine.......................		2
4. *Conglomerate*, the matrix a fine grained, quartzose sandstone somewhat calcareous, with white feldspar in grains and pebbles. Pebbles flat, lying on their sides..............................	1	6
3. Quartzite, calcareous-granular, with calcite.......		2
2. Quartzite, coarse, translucent-granular, with feldspar and limestone...........................		4
1. Limestone, white, coarse, with graphite and mica..	5	

In Madoc, *conglomerate* occurs again, with calcareous matter; and in a higher position is a ridge "consisting of micaceous schists, beyond which, for 300 yards, ridges of a decided *conglomerate*, with distinctly rounded pebbles, enveloped in a matrix of micaceous schist, alternate with ridges of schist containing few or no pebbles."*

"Still farther north, another band of *conglomerate* occurs, associated with fine grained, soft, micaceo-silicious, feldspathic schist. The matrix of the conglomerate weathers white, and appears to be a dolomite. The pebbles, of which the largest may be six inches in diameter, are chiefly quartz, but there are also, pebbles or masses of feldspar, and a few of calc-spar. The quartz pebbles are for the most part, distinctly rounded, and their colors various, some being internally bluish, some white, and others pinkish. The feldspar is red and white, and the calcspar white. The dip of the rocks appears to be southward of east, but the slope is irregular, and may probably be 35° or 40°" (p. 33.)†

The anorthosite rocks are fully described. Their bedding is very obscure, but they occur in belts conformable with the limestones and the orthoclase gneisses. The hypersthene rock of northern New York, and of the Isle of Skye, are pronounced of the same character. Near Bay Saint Paul, is a mass of titaniferous iron ore in the anorthosite, 90 feet in width, by about 300 feet in length (p. 35.)

The following is a synopsis of a general section across a portion of the Laurentian (p. 45:)

		Feet.
10.	Anorthosite above the Morin limestone (conjectural)	10,000
9.	Orthoclase gneiss (and a band of quartz)	3,400
8.	Proctor's Lake limestone	20
7.	Orthoclase gneiss	1,580
6.	Grenville limestone	750
5.	Orthoclase gneiss	3,500
4.	Great Beaver Lake and Green Lake limestone	2,590
3.	Orthoclase gneiss	4,000
2.	Trembling Lake limestone	1,500
1.	Orthoclase gneiss of Trembling Mountain	5,000
		32,750

*Mr. Macfarlane subsequently describing these conglomerates, says they are "lithologically not unlike some of the Huronian rock." Whereupon, Sir W. E. Logan, in a note replies: "It is not to be inferred from the presence in them of a schistose conglomerate, that therefore, they are Huronian" (*Geology of Canada*, 1866, p. 93.)

†Sir William Logan never omits mention of these conglomerates, when having occasion to furnish a synopsis of the Laurentian. See, for instance, his announcement of organic traces (*Quar. Jour. Geol. Soc. Lond.*, Feb. 1865.)

In reference to the Huronian series, Sir William Logan makes statements from which the following extracts are drawn (p. 90:)

"On Lake Temiscaming, the Laurentian orthoclase gneiss is followed by a slate conglomerate. The finer parts of the rock are dark gray, weathering to dark green; they are of a uniform grain, and, being at the same time, argillaceous and silicious, they present the characters of a hard compact slate. Some parts not so fine in texture, are a hard, dark gray sandstone weathering to a dingy olive green. In both cases, the rock frequently exhibits the character of a compact conglomerate, holding pebbles and bowlders, sometimes a foot in diamater, of the subjacent gneiss, from which they appear to be principally derived."*

Some other conditions of the formation are described as finer textured, penciled in transverse fracture by fine colored lines; another as a "very close grained, compact, dark gray mica slate. When cleavage exists, the planes cut the pebbles in common with the matrix." It is never fit for roofing slates. To this slate conglomerate succeeds a quartzyte, apparently 400 to 500 feet thick.

"On the Sturgeon, Wahnapitæ and Whitefish rivers, there is usually interposed between the Laurentian gneiss and the recognized Huronian rocks, a mass of rather coarse grained greenstone or diorite."

The general section in the region of these three rivers, northeast of lake Huron, and stretching to lake Wahnapitæ—is represented by the following abstract (p. 52):

5. Quartzite, white and greenish, with beds of quartz conglomerate.
4. Slate conglomerate.
3. Limestone, much shattered and disturbed.
2. Slate conglomerate.
1. Silicious strata, fine grained, with greenish quartzite interstratified.

In the region nearer lake Huron, and along the northern shore westward, lies the typical part of the Huronian. As to its relations with the Laurentian, we have from the Canadian geologists, only the following information (p. 55):

"On the coast line, between the Mississagui and the Thessalon rivers, a distance of about 25 miles, the gneiss extends from within

*But it will be remembered that no contact between these so-called conglomerates and the older gneisses had been observed: nor has it to this day. Nor, if such observation had been made, would the circumstance prove these "conglomerates" in immediate chronological succession to the gneiss. Palæozoic limestones were frequently observed resting on gneiss, in the progress of the Canadian survey. The pebbles in this conglomerate may have been derived from the gneiss, and laid down on the gneiss, after the interposition of the events of a geologic age of land history.

about four miles of the former, to within about the same distance of the latter; but, it is very much disturbed by intrusive granite and greenstone, and although there are great exposures of rock, it is very difficult to make out how the stratified portions are related to one another. The gneiss extends to the vicinity of a small stream, about a mile and a half above Les Grandes Sables, and what is supposed to be the lowest Huronian mass of that part, occurs about half a mile above the stream. It consists of a gray quartzite which *abuts against one mass of gneiss and runs under another*, and appears to be much broken by, and entangled among, the intrusive rock; but judging from a transverse measure in one part, its thickness would not be far from 500 feet. Farther west, after passing an exposure of stratified amygdaloidal trap, which would apparently overlie the [this] quartzite, the rocks for about two miles east of the Thessalon, appear to consist of green, fine grained chloritic and epidotic slate ["diabase slate"] alternating with masses that have the aspect of trap."

The following is an abstract of the general section in this region (pp. 55–7):

		Feet.
13.	White quartzite	400
12.	Yellowish chert and impure limestone	200
11.	White quartzite, frequently vitreous	1,500
10.	Yellowish chert, with thin and very regular beds	400
9.	White quartzite, frequently vitreous	2,970
8.	Red jasper conglomerates. Sometimes fine white quartzite. Greenstones intercalated	2,150
7.	Red quartzite with interstratified greenstones	2,300
6.	Slate conglomerate with interstratified greenstones	3,000
5.	Limestone, compact, green, drab or gray, thin bedded	300
4.	Slate conglomerate [as previously described]	1,280
3.	White quartzite, sometimes pebbly	1,000
2.	Chloritic and epidotic slates [probably eruptive]	2,000
1.	Gray quartzite, thickness doubtful	500
		18,000

It will be desirable to contemplate the above section separately from the section of "Huronian" rocks reported from the north shore of lake Superior. It is quite possible that the two sections relate to rocks belonging to different geological ages.

"On lake Superior, the Laurentian gneiss is succeeded by slates generally of a dark green without, and often of dark gray in fresh fracture, which at the base appear occasionally to be interstratified with beds of a feldspathic character, of the reddish color belonging to the subjacent gneiss. Sometimes these beds are a combination of feldspar and quartz, occasionally with the addition of hornblende and, in some of the beds, the hornblende predominating, gives them a general green color. Some of the beds have the character of diorite; others, that of mica slate, and a few present that of quartzite" (p. 52).

These seem to be identical with the lowest rocks of the iron-bearing series of Vermilion lake, a part of Lawson's Keewatin. They exhibit the well-known transition from Laurentian gneiss to crystalline schists. The mica schist is "nascent."

"Rising in the series, the dark green slates become interstratified with layers holding a sufficient number of pebbles of different kinds, to constitute *conglomerates.* The pebbles appear to be all derived from altered rocks; they greatly vary in size in different places, and occasionally measure a foot in diameter. Where the *slate conglomerates* have been worn by the action of water, the pebbles are generally worn down equally with the rest of the surface; and though a very distinct picture of them is presented on such a surface, where the water or weather appears to have had an influence in bringing out a well defined contrast in colors between the pebbles and the slate, at the same time producing a contrast between parallel bands of the slate on the terminal edges of the laminæ, it yet often happens, unless the pebbles are of white quartz, that they are very obscurely distinguishable on fracturing the rock — both the pebbles and the matrix having a gray color, and showing very little apparent difference in mineral character. On some of these pictured surfaces, small opaque, white feldspathic crystals occasionally spot the whole surface of the rock — the pebbles equally with the slaty matrix. The rock has nowhere on the lake been observed to display true slaty cleavage, independent of the bedding; but it often exhibits a jointed structure, and the divisional planes cut through the pebbles without the smallest deflection."* (pp. 52 and 53).

It is impossible to identify this description with the description of the Huronian rocks north of lake Huron. There are some circumstances which readily explain the course taken by the Canadian geologists, but the identification made as early as 1848, has perpetuated misconceptions, and bred unintelligible confusion. I have some confidence that we may be near the solution of the puzzle.

* The whole of the above description applies exactly to the lower part of the "Ogishke Conglomerate," on the shores of Ogishke Muncie or Kingfisher lake, in Minnesota, eighty miles west of Thunder bay. I shall return in the sequel, to a discussion of this identification. The stratigraphical position of the "Ogishke Conglomerate" has been in doubt; but if this parallelism is correct, it belongs near the bottom of the Vermilion lake iron-bearing schists.

The same basal slaty conglomerate occurs at other points along the north shore.

"A considerable thickness of these conglomerate or pebbly slates, is exposed at the mouth of the river Doré, near Gros Cap, about five miles above the mouth of the Michipicoten river. The strike of the rock is very regular, being about east and west, while the dip is highly inclined, the beds being not more than from ten to fifteen degrees from a vertical attitude; but the slope is for part of the distance, to the north, and for the remainder, to the south; there is not, however, supposed to be any repetition of the measures, which are given in descending order" (p. 53).

		Feet.
21.	Green slate rock, with a few scattered pebbles through some parts of it, in other parts conglomeratic; the sedimentary layers not distinctly marked; rock with a jointed structure; joints cutting straight through the pebbles............	40
20.	Green pebbly slate; edges of laminæ well marked, producing a ribboned appearance; pebbles chiefly gneiss, granite or syenite......................	300
19.	Green slate rock similar to 20 and 21.............	550
18.	Green pebbly slate...............................	170
17.	Measures covered by sand........................	90
16.	Green slaty conglomerate, with large pebbles of igneous or altered rock........................	15
15.	Green slate rock with many pebbles.............	30
14.	Green slate with finer pebbles....................	40
13.	Green slate rock, with scattered, large pebbles....	10
12.	Green slate rock, like 13..........................	130
11.	Green slate conglomerate, with boulders sometimes a foot in diameter, in a slaty matrix............	5
10.	Measures concealed by sand.....................	30
9.	Green slate rock with many pebbles..............	30
8.	Green slate rock with pebbles.....................	30
7.	Measures concealed by sand..........................	20
6.	Green slate rock, very pebbly, sedimentary layers finely waved, water worn surface much pitted...	30
5.	Green slate rock, bedding very even, appears to be somewhat talcose toward the top..............	20
4.	Green slate rock like 5..........................	15
3.	Green slate rock with even bedding, slightly unctuous and talcoid in several of the divisions.......	20
2.	Green slate rock, a few scattered pebbles in parts, flattened in direction of the strata.............	90
1.	Green slate rock with large pebbles and small boulders of granite or gneiss, quartz and a chert-like stone (p. 54)............................	35
		1,700

The foregoing section is almost a continuous "slate conglomerate," or pebbly slate, and but for the so-called "talcose" matter, might hastily be identified with the slate conglomerate of the Thessalon valley. But, as will be shown, it is a different slate. The descriptions again apply to the Ogishke conglomerate. In Minnesota, this conglomerate is only one member of the iron-bearing series. In accordance with that fact, Sir William Logan adds:

"At the Doré, a much larger amount of the slate formation than is here given comes in behind the preceding section; but it was so covered with trees and moss, at the time of the examination, that it was found impossible to follow out the details. Toward the lower part, it *assumes more the character of the gneiss* which usually succeeds it, and becomes *interstratified* with reddish-yellow feldspathic layers; but sufficient data have not yet been ascertained to determine what may be the total thickness of the slate rock in this part, though it must probably attain several thousand feet" (p. 54).

Other localities on lake Superior where slate conglomerates and jasper conglomerates occupy a similar position, are between the Goulais river and Batchewahnung bay. The same seem to extend along the shore of the Michipicoten river, on each side, eight or nine miles. It occurs also, a little farther west on the coast, and again about five miles south of Otter Head (p. 63).

"Another locality is Thunder bay, where they occupy the coast for a distance of ten miles, immediately below the mouth of the Kaministiquia river, on the north side, leaning in a narrow strip against the gneiss of the lower series. It is not improbable that they may present a narrow belt in the valley of the Kaministiquia They occupy the coast for about seven miles on each side of the New Pic river; while an interval from this to a point two miles beyond the Old Pic river, including the coast of Peninsula Bay and Harbor, and Pic island, is composed of trap. Beyond this, the chloritic slates occupy about fifteen miles of the coast, extending to the neighborhood of the deep cove which receives the Pike river" (p. 64).

A characteristic feature of the Keewatin iron-bearing series is indicated in the description of the junction of these rocks with the gneiss on the Kaministiquia river, in the vicinity of the Grand Falls:

"At the lower end of the portage, where the series makes its appearance, the rock resembles a massive syenite, in some parts red, and in others, whitish, but is probably a hornblendic gneiss in which the lamellar arrangement of the constituent minerals is obscure, as the rock gradually passes into such a gneiss. Resting on it *conformably*, there occurs a series of dark greenish blue, or greenish black slates, the one rock *passing almost imperceptibly into the other*. . . At each rapid part of the river above the Grand Falls, there is a greater or less development of these rocks, most frequently presenting the more distinctly stratified part of the gneiss. The best exposure of the slate is at the Three Discharges, about four miles above the Grand Falls, where the rocks are observed to pass from the gneiss to the slate." The vertical thickness at this place is about 2,300 feet.

"Toward the bottom, near the junction with the gneiss, the slates are of a bluish and occasionally of a brownish color. They are intersected by numerous parallel joints which divide the mass into rhomboidal forms of singular regularity. The middle and upper portions of the section are usually of a pistachio green, resembling the green of epidote, and frequently in part present a jaspery character. They are hard and compact, usually with a conchoidal, but sometimes with a splintery fracture. The divisional planes are frequently covered with mica, and in such cases, the rock may almost be termed a mica slate" (p. 65). Similar rocks continue as far as Dog lake.

The foregoing description applies perfectly to the passage from the iron-bearing formation to the gneisses, as observed in a hundred places in northeastern Minnesota. No structural unconformity exists, as a fact of present observation. It is not intended to assert, however, that it never existed.

The schists observed along the north shore of lake Huron, in which the Bruce and Wellington and Wallace mines were worked, constitute Logan's "Lower Copper-bearing series." As these were identified with the series of slates just described, they were also made to represent the Lower Copper-bearing series. Neither series could be identified with the copper rocks of the south shore of lake Superior. But as those rocks were observed on the north shore at a higher stratigraphic level, they were demoninated by Logan the "Upper Copper-bearing rocks." But in thus fixing parallelisms, he strangely overlooked the importance of a series between the proper Cupriferous rocks above and the pseudo-Cupriferous rocks below. These were the real Lower Copper-bearing rocks, though Logan joined them to the Upper, or south shore Cupriferous. His treatment of the so-called "Upper Cupriferous rocks" will appear from a few extracts.

"The Huronian formation of Lake Superior [the real iron-bearing series] is *unconformably* overlaid by a second series of copper-bearing rocks, which may be conveniently divided into two groups. Of these the lower consists of bluish slates or shales interstratified with sandstones and beds of columnar trap; and the upper, of a succession of sandstones, limestones, indurated marls and conglomerates, also interstratified with trap which is often amygdaloidal" (p. 67).

The following is a characterization of the lower group of the Upper Copper-bearing series, (p. 67):

"The base of the formation where seen in Thunder Bay, in contact with the subjacent green slates or slate conglomerates, presents conglomerate beds probably of no great thickness, composed chiefly of quartz pebbles, with a few of red jasper, and some of greenish, chloritic slate, in a greenish, arenaceous matrix, consisting of the same materials in a finer condition. These are followed by a set of very regular, even layers of chert, sometimes approaching a chalcedony, varying in color from nearly white, through different shades of gray to black, and in thickness, from less than half an inch to six inches, and even a foot. These are separated from one another by thin layers of dark gray dolomite, weathering rusty-red and present a striking ribbon-like appearance. Occasionally, thicker beds of dolomite occur, sometimes highly crystalline, separating aggregated bands of the ribbon-like strata; and these dolomitic beds, as well as the chert bands, are sometimes interstratified with argillaceous layers" (p. 67).

"In the vicinity of disturbed parts, the chert sometimes passes into chalcedony and agate, and small cracks are filled with what appears to be anthracite. Some of the chert bands appear to be made up of a multitude of minute, irregular, closely aggregated, sub-globular bodies, floating as it were, in the silicious matrix. Anthracite seems to be present in the centre of some of these, leading to the supposition that the color of the black chert, even where these shapes are not detected, may be owing to the presence of carbon. In some parts of these oölitic chert layers, small blood-red jasper spots occasionally become interstratified with the black. . . .

"Higher in the formation, argillaceous slates become interstratified with argillaceous sandstones in such an ealterd condition that it is often difficult, at first sight, to say whether the latter may not be trap layers. . . In some parts of the vertical thickness, calcareous layers are occasionally interstratified among the slates, but few of them are pure enough to be entitled to the appellation of limestones. . . "On the Kaministiquia, the lowest part of the formation occurs near Grand Falls. Its immediate junction with the rock on which it rests is concealed from view. . . The argillaceous strata visibly reach to within a short distance of the pond [in which the junction is supposed to occur] (p. 68).

"The general color of the rock is here black, weathering to a rusty brown. Some of the beds being soft and shaly, are easily decomposed by atmospheric influences, while the mass is, for the most part, a hard argillaceous slate. The whole formation appears to be more or less calcareous, and among the lower members, thin beds of magnesian limestone occur, sometimes alternating with thin beds of black chert" (p 68–9).

"In Thunder bay, and on the coast above it, trap bands, conformable with the stratification, are interstratified in several parts of the formation, but they occur in greatest thickness toward the bottom, not far above the chert-beds, and at the summit, overlying the whole of the mass. . . In all cases, the trap presents a very striking sub-columnar structure at right-angles to the plane of the stratification; and the crowning overflow gives a peculiar aspect to the whole region occupied by the formation to which it belongs. The overflow is from 200 to 300 feet thick, and the whole of the associated rocks, to the base of the formation, may possess a volume of between 1,500 and 2,000 feet." (pp. 69, 70).

The foregoing is a good description of the black slates and the slate-conglomerate of the so-called Huronian series north of lake Huron. In the latter region, columnar trap (or gabbro) does not constitute a persistent "crowning overflow", as far as the descriptions given by the survey indicate, but interbedded traps are present, and the lithological characters of the formation—the black shale, the cherty and flinty layers, the oölitic structure, the even beds, the proximate horizontality—and no other known formation about lake Superior presents any close resemblance to the Huronian strata. These black slates of Thunder bay, moreover, are now known to extend westward into Minnesota, and to overlie unconformably a mass of vertical, sub-crystalline schists in the same manner as at Thunder bay.

As to the upper group of the Upper Copper-bearing series, little needs to be said here, as this is the well known Cupriferous series of the south shore, consisting chiefly of intercalated beds of sandstone, conglomerate and trap, with occasional beds of limestone, and attaining an aggregate thickness of 6,000 to 10,000 feet. The trap is often amygdaloidal, and native copper occurs in irregular grains and strings and masses up to ten pounds in weight. Sir William Logan's discussion of this formation does not possess theoretical significance.

In an appendix to the report of 1863, Sir William Logan states that "the Taconic system of Emmons, which he supposed to be a distinct series of rocks more ancient than the Potsdam, appears to consist, for the greater part at least, of the strata of the Potsdam and Quebec groups. The Upper Copper-bearing rocks of lake Superior are regarded as occupying the position of the Quebec group, to which they bear some resemblance in lithological and mineralogical characters. They may, perhaps, include the Potsdam group."* [Compare the views of Foster and Whitney.]

The following is a summary of Sir William Logan's successive views on the classification of the Azoic rocks of Canada:

DIVISIONS OF ARCHÆAN ROCKS RECOGNIZED BY LOGAN.			PUBLICATION.
Metamorphic Series.			1845.
Lower Group.	Upper Group (Lake Sup).		1846.
Gneiss, Mica slate.	Quartz rock, etc.		1847.
Granitic or Metamorphic Group.			(1848) 1850.
Metamorphic or Gneissoid Group.			(1849) 1850.
Metamorphic Group.			1851.
Gneiss, etc.	Cambrian.		(1851) 1852.
Laurentian Series.			(1852) 1854.
Laurentian Formation.	Huronian Series (Murray).		(1853-7) 1857.
Laurentian | Upper Laurentian, or Labradorian.	Huronian.		1857.
Laurentian.	Huronian. (Lower Copper bearing rocks.)	Upper Copper-bearing rocks.	(1863).
Laurentian Series.	Huronian Series.	Upper Copper-bearing rocks. (Quebec group) Lower group | Upper group	1866.

NOTE.—Dates of presentation of reports are placed in parentheses.

One of the important features of the volume on the Geology of Canada, 1863, was the introduction of the "Quebec Group," supposed to be a group of strata occupying a position between the characteristic part of the Calciferous and the Hudson River shales, and specially investigated in the vicinity of Quebec. Sir William Logan was so good a physical geologist that when he had given his sanction to the proposal, a strong predisposition was given to American opinion. Thus the Quebec group had the sanction of James Hall, E. Billings and T. S. Hunt, and found admission to the second edition of Dana's "Manual of Geology." We have seen, however, what misgivings on the subject were entertained by professor Hall, and how he permitted his respect for Sir William Logan to compromise his own palæontological convictions. The "Group" remained a stumbling-block and an enigma in American geology until, failing in prestige during the last decade, it received its final *coup de grace* at the hands of the Survey itself, in 1889.†

*Geology of Canada, 1863, p. 934.

†Second Report on the Geology of a portion of the Province of Quebec. R. W. Ells. *Geol. Sur. Canada, Annual Report*. 1887-88. Montreal 1889.

It would be profitless to pursue the history of an opinion which has already lost its hold on credence, even if were the purpose of the present memoir to deal with discussions exclusively palæontological. But the rocks have been, in some regions, so confounded with those of the so-styled Taconic, that the investigation of the latter involves a review of opinion on the former. For the convenience of the student, therefore, the titles of the principal papers bearing on the discussion, are here appended*

*1861. Logan, Sir W. E.
In "Correspondence of Joachim Barrande, Sir William Logan and James Hall, on the Taconic System, and the Age of the Fossils found in the Rock of northern New England and the Quebec Group of Rocks." *Amer. Jour. Sci.* II, xxxi. 210-226.

1862. Logan, W. E.
Determination of Age of Quebec Rocks. *Amer. Jour. Sci.*, II, xxxiii, 105-6.

1862. Logan, W. E.
Considerations relating to the Quebec Group and the Upper Copper-bearing Rocks of Lake Superior (Read before Montreal Nat. Hist. Soc.), *Amer. Jour. Sci.*, II, xxxiii, 320-327.

1863. Logan, W. E.
The Quebec Group. *Geology of Canada*, 1863, pp. 225-397.

1863. Logan, Sir W. E.
Letter addressed to Mr. Joachim Barrande, on the Quebec Group at Point Lévis, Montreal, pp. 1-14. Reprinted, *Amer. Jour. Sci.*, II, xxxvi, 366-377.

1866. Logan, Sir W. E.
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See, also, the references on the Taconic System, many of which bear on the Quebec Group.

JOSIAH D. WHITNEY.

1847. Josiah D. Whitney and Joseph W. Foster were assistants, in 1847, of Dr. C. T. Jackson in his survey of the "mineral lands" of lake Superior; and Mr. Whitney continued in the same capacity in 1848. In 1849 and 1850, Messrs. Foster and Whitney succeeded Dr. Jackson, and their Annual Report is dated Boston, Nov. 5, 1849. Mr. Whitney's observations in 1847, were restricted to the copper-bearing rocks, mostly of the Ontonagon district, and he had no occasion to introduce general views in his report; but a part of Mr. Foster's notes relate to a traverse from lake Superior over the Menominee region, to Green bay.* Mr. Whitney does not appear to have transmitted to Dr. Jackson, anything except barometric observations as the result of work in 1848 (*op. cit.*, pp. 644-646).

1849. In their report of 1849, Messrs. Foster and Whitney say: Experience "has demonstrated that the veins of copper and its ores in the sandstone and conglomerate are not to be relied on, and that when worked even to an inconsiderable depth, they give out. . . All the productive lodes are confined to the ranges of trap. . . The associated sandstone and conglomerate belong to the Silurian system, and rest at the base of all the fossiliferous rocks" (p. 607.)† Accompanying this report are four geological maps: 1. Ile Royale; 2. Keweenaw Point; 3. The district between Keweenaw Bay and Chocolate River; 4. The district between Portage Lake and Montreal River. On the 3d and 4th of these Maps, the term "Azoic" is introduced. The 4th Map was transmitted to the Secretary of the Interior by a letter dated July 25th, 1849. The date of transmittal of the other is not known, but probably, the same month. On the 3d Map, the explanatory legend presents the following arrangement:

Aqueous,	Base of the Silurian System,	Sandstone.
Metamorphic,	Azoic System,	Quartz. Saccharoidal limestone Schistose Rocks.

*The Report is found on pp. 773-784 of that chaos of literary, scientific and statistical matter called Jackson's Geological Report, occupying pages 371-801 of "*Annual Message and Documents*," 1849-50, Part III—except pages 605-624, including four maps, occupied by Foster and Whitney's report for 1849, which is interjected into the midst of Jackson's report.

†Dr. Jackson, (*op. cit.* p. 399), says "Anterior to my researches, the red sandstones of Lake Superior were supposed to be the "old red," and subsequently the opinion that they belonged to the Potsdam, N. Y., series, gained ground; but, from the facts that the mineral composition, associations and contents were identical with the sandstones of Nova Scotia, Connecticut, Massachusetts and New Jersey, and that the disturbing agency which moved them was in the same direction and produced similar, if not identical results, I was disposed to regard those rocks as of the same age, or as of the New Red sandstone series. This idea has been confirmed."

Igneous Formation,	More recent than the Azoic, but older than the Silurian,	Trappean Rocks. Granite. Basalt.

The legend on the 4th Map is as follows:

Aqueous Formation,	Lower Silurian System.	Lower Magnesian Limestone. Sandstone. Conglomerate.
Metamorphic,	Azoic System,	Schistose Rocks.
Igneous,	Contemporaneous with Silurian,	Trap. Jasper and Quartzose Porphyry.
	More recent than Azoic,	Granite.

1850. The first part of the final report, relating to the "Copper Lands," was transmitted April 15, 1850.* In the IVth chapter, the authors, treating of "Stratified and Sedimentary rocks," comprise them under three general divisions:

III. Compact or Lower Magnesian Limestones. 3. Birdseye and Black river limestone; 2. Chazy limestone; 1. Calciferous sandstone.

II. Inferior Sandstone. Potsdam Sandstone.

I. Conglomerate. Not strictly a sedimentary rock, but a volcanic tuff.

Speaking more particularly of the conglomerates, the authors state concerning the pebbles: "Their surfaces do not present that smooth, polished appearance which results from the attrition of water,† in fact, a close observer can readily distinguish between those which have been recently detached from the rock and those which have been for a time exposed to the recent action of the surf. The conglomerate appears to have been formed too rapidly to suppose that the masses were detached and rounded by the action of waves and currents, and deposited with silt and sand on the floor of the ancient ocean; for while the contemporaneous sandstone remote from the line of volcanic foci, does not exceed three hundred or four hundred feet in thickness, the united thickness of the conglomerate bands, in the vicinity of the trappean range on Keweenaw Point, exceeds five thousand feet. As we recede for a few miles from the line of the volcanic fissure, these amygdaloidal pebbles disappear, and are replaced by arenaceous and argillaceous particles. We are therefore disposed to adopt the theory as to the origin of such masses first suggested by Von Buch: 'When basaltic islands and trachytic rocks rise in fissures, friction of the elevated rock

Report on the Geology and Topography of a Portion of the Lake Superior Land District in the State of Michigan. By J. W. Foster and J. D. Whitney, United States Geologists. In two parts. Part I, Copper Lands. Washington, 1850, 8vo, pp. 224, with a Map and xii Plates. (Being *Ex. Doc.* No. 69, House of Representatives, 31st Cong, 1st Sess.)

†The "attrition" which rounds shore pebbles is not "attrition of water". Perhaps the authors mean attrition *in* water.

against the walls of the fissures, causes the elevated rock to be enclosed by conglomerates composed of its own matter. The granites composing the sandstones of many formations have been separated rather by friction against the erupted volcanic rock than destroyed by the erosive force of a neighboring sea. The existence of these friction conglomerates, which are met with in enormous masses in both hemispheres, testifies to the intensity of the force with which the erupted rocks have been propelled from the interior through the earth's crust. The detritus has suddenly been taken up by the waters, which have then deposited it in the strata which it still covers'.* Those pebbles having a highly vesicular structure may have been ejected through the fissures in the form of scoriæ while in a plastic state, and have received their rounded shape from having been projected through water—on the same principles as melted lead when dropped from an elevation assumes a globular form '.†

On page 112, in a note, the authors cite similar conglomerates of eruptive origin, in the Hawaiian and Fiji islands, as described in the report by professor Dana, on the Geology of the Exploring Expedition.

In speaking of the sandstone, they do not, like Houghton, discriminate between that which is interbedded with conglomerate layers, and that which overlies both, though they recognize, as Houghton did, the synclinal arrangement of the beds forming the lake basin, and give a theoretical diagram illustrating it. They say: "During the deposition of the sandstone, numerous sheets of trap were ejected and flowed like lava streams, and the igneous and aqueous products were so intermingled as to present the appearance of having been derived from a common origin." (p. 110.) The general discussion, however, relates to that which Houghton had denominated "Lower or Red Sandstone."

The method of geologic action which gave origin to the Cupriferous formation is conceived by the authors as follows: The entire region was the bed of an ocean of heated waters, and volcanic paroxysms were frequent. Numerous fissures through the crust of the earth resulted. "Along the lines of these fissures existed numerous volcanic vents, like those observed at this day in Peru, Granada and Java, which were characterized by periods of activity and repose. From these vents were poured forth numerous sheets of trap, which flowed over the sheets of sand and clays then in progress of accumulation. During the throes and convulsions of

*Geognostische Briefe, S. 75-82.

†Report on Copper Lands, pp. 99, 100.

the mass, portions of rock would become detached, and rounded simply by the effects of attrition, and jets of melted matter be projected as volcanic bombs through the air or water, which on cooling would assume spheroidal forms, while other portions of the rock, in a state of mechanical division, would be ejected in the form of ashes and sand, which mingling with the water, would be deposited, as the oscillations subsided, among the sand and pebbles at the bottom of the sea. During the whole of this period of volcanic activity, the sands which now form the base of the Silurian system were in progress of accumulation, and became mingled with these igneous products" (p. 120). "Thus, alternating bands of igneous and aqueous rocks were formed", and thus, unlike the theory of Dr. Houghton, which regarded the trap sheets as dykes, our authors contemplate them as overflows.

1851. The second part of Foster and Whitney's report on the Mineral Lands of Lake Superior* was transmitted to the secretary of the Senate, November 20, 1851. It is a comprehensive, thorough and scientific presentation and discussion of the general and economic geology of the region embraced — with the exception of matters treated in Part I. It is probably the most meritorious production to that time issued under the auspices of the general government. The lithographed engravings are superior, but the wood-cuts are obscure, and the typography and paper cheap and unworthy. This volume has become celebrated as the one in which the "Azoic System" was established in America.

In the preliminary chapter, a general classification of the rocks of the district is given, of which the following is the lower part :†

Aqueous.	Silurian System.	Potdsam Sandstone,‡ etc.	
Metamorphic.	Azoic System.	Beds of Quartz and Saccharoidal Marble. Chloritic, Talcose and Argillaceous Slates Gneiss, Mica and Hornblende Slate.	
Igneous.	Of various ages.	Trappean volcanic rocks.	Masses of Specular and Magnetic Oxide Iron. Hornblende and Serpentine rocks. Basalt, Amygdaloid, Greenstone or Dolerite Porphyry.
		Plutonic rocks.	Feldspar and Quartz rock. Syenite. Granite.

"Below all the fossiliferous groups of this region" say the authors, "there is a class of rocks consisting of various crystalline

**Report on the Geology of the Lake Superior Land District.* By J. W. Foster and J. D. Whitney, United States Geologists. Part II, The Iron Region, together with the General Geology, March 13, 1851: Ordered to be printed, Washington, 1851 [8-vo., pp. 406, 36 plates of illustrations, and a geological map of the upper Peninsula of Michigan and of the north shore of lake Superior from Sturgeon bay eastward.]

†It will be remembered that in all the stratigraphic tables of the present memoir, the older rocks stand below. This is an inversion of the arrangement adopted by Foster and Whitney, and most of the earlier writers.

‡The age of the Potsdam sandstone was discussed by the authors in *Proc. Amer. Assoc.*, Cincinnati meeting, 1851, (pp. 22-38).

schists, beds of quartz, and saccharoidal marble, more or less metamorphosed, which we denominate the Azoic system. This term was first applied by Murchison and De Verneuil* to designate those crystalline masses which preceded the Palæozoic strata. In it, they include not only gneiss, but the granitic and plutonic rocks by which it has been invaded. We adopt the term but limit its signification to those rocks which were detrital in their origin, and which were supposed to have been formed before the dawn of organized existence.†

Obviously, there is a degree of indefiniteness about this definition: 1st. Remains of organization may be found in rocks which "preceded the Palæozoic" as understood by Murchison: 2d. Not only gneiss but granite and syenite may yet be proven of detrital origin. Thus the base of the Palæozoic may be lowered either by the discovery of fossiliferous rocks between the Potsdam and the top of the Azoic as known to Foster and Whitney, or by the discovery of fossils within the Azoic rocks as thus known; and the base of the Azoic may be raised by the demonstration of the original igneous condition of the gneisses, or lowered by the demonstration of the original sedimentary condition of the granitoid masses. These, however, are only practical difficulties in the application of the conception of Foster and Whitney. The conception as above defined is clearly delimited and rational. By a reasonable application of the conception, the Azoic system would always embrace the strata beneath the oldest at any time found to be fossiliferous‡ and above the rocks at any time held to be igneous in origin. This was very nearly Emmons' first conception of the Taconic, nine years earlier; but he recognized the Potsdam sandstone as the base of the Silurian system, and only by provisional inference, the base of the Palæozoic series so that when strata older than the Potsdam were found fossiliferous, he changed his view in reference to the azoic character of the Taconic, and thereafter insisted that it was a zoic system.

"Most of these rocks [of the Azoic system,] the authors state, "appear to have been of detrital origin, but greatly transformed by long exposure to heat. They are sub-crystalline or compact in

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* *The Geology of Russia in Europe and the Ural Mountains*, vol. i, p. 10, 1845,. See also, *Proc. Geol. Soc. Lond.*, vol. iv, p. 602, 1845.

†Foster and Whitney, *Rep.*, p. 3.

‡Mr. Whitney has indicated the possibility that the upper limit of the Azoic might have to be placed lower than the base of the Potsdam sandstone. "If we find in this country, a series of fossiliferous beds below those at present recognized, and whose organic contents cannot be considered as being of Lower Silurian type, let us give them a new name which shall not involve us in any Cambrian controversies." (*Amer. Jour. Sci.*, II, xxiii, p. 314).

their structure, and rarely present unequivocal signs of stratification. They exhibit the most violent dislocations; in one place the beds are vertical, in another, reversed, and in another, present a succession of folded axes. Intermingled with them is a class of rocks whose igneous origin cannot be doubted, and to whose presence, the metamorphism so characteristic of this series, is in some measure to be ascribed. They consist of varying proportions of hornblende and feldspar, forming traps and basalts, or, where magnesia abounds, pass into serpentine rocks. They appear in some instances to have been protruded through the pre-existing strata, in tne form of dikes or elvans, in others, to have flowed in broad lava streams over the ancient surface; and in others, to have risen up through some wide-spreading, expanding fissure, forming axes of elevation" (p. 8).

"Many eminent geologists maintain that the lowest stratified rocks are but portions of the Silurian or Cambrian system; and that from long continued exposure to heat the lines of stratification have become obscure, and all traces of organic remains obliterated. Our investigations in this district have led us to a different conclusion. If the Potsdam sandstone rests at the base of the Palæozic series; if from that epoch we are to date the dawn of animal creation, there is in this district a class of obscurely stratified rocks interposed between the Silurian system and the granite—rocks distinct in character, unconformable in dip, and destitute of organic remains" (p. 10).

The authors quote from the early reports of "Mr. Logan, the distinguished Provincial geologist of Canada, for the purpose of stating that the two-fold division of these rocks, described by Mr. Logan* has not been observed on the southern shore.

In reference to the blending of igneous and sedimentary characters in the Azoic rocks of the south shore, the authors quote from de la Beche a passage which, though it possesses only the authority of an individual, needs to be borne in mind in the more recent attempts to interpret the rocks in question, whether on the south or the north shore. This is the passage:

"There is so intimate a mixture of compact and schistose trappean rocks with the argillaceous slates [of Bossiney, Cornwall] that the whole may be regarded as one system, the two kinds of trappean rocks having been probably erupted, one in a state of igneous fusion, and the other in that of an ash, during the time that

Report of Progress, 1846-7, p. 10. It is clear that the upper division here indicated in the metamorphic rocks is what was afterward denominated *Animike*. But we shall return to this point. It is also apparent that this division, if not entirely wanting on the southern shore, is very inconspicuously developed.

the mud now forming slates, was deposited; the mixture being irregular from the irregular action of the respective causes which produced them, so that, as one may have been derived from igneous action, and the other from the ordinary abrasion of pre-existing solid rocks, they were geologically contemporaneous."

Some further remarks by the authors relate specifically to the rocks on the south shore of lake Superior. "Many of the igneous rocks of this region form neither long lines of dykes nor axes of elevation, but broad sheets, bearing the same relation to the slates that the trappean bands of Keweenaw Point do to the conglomerates. Many of the slates appear to be composed of pulverulent greenstone, as though they might originally have been ejected as an ash, and subsequently deposited as a sediment, and pass by imperceptible gradations from a highly fissile, to a highly compact slate." Some of these phenomena are compared with sub-oceanic salses, "pouring forth streams of pulverulent material to be mingled with ordinary fragmental deposits.

Messrs. Foster and Whitney, in concluding their account of the general geology of the Azoic system, seek to strengthen its establishment by pointing out the existence of a similar series of rocks in other states—in Minnesota, Arkansas, Missouri, New York, Pennsylvania and Virginia. They refer to the evidence supplied by the brothers Rogers, that the series of obscurely stratified rocks known as the gneissoid series, flank the Appalachian chain on the east throughout its entire extent. Turning to the Old World, they cite the well known witnesses to the existence of similar azoic rocks in Scandinavia, Great Britian and Bohemia (pp. 33, 34.)

As to the origin of the mass of magnetic oxides of iron, having shown that they occur in beds instead of true veins, they consider the evidences of an igneous and of a metamorphic origin, and conclude: "On the whole, we are disposed to regard the specular and magnetic oxides of iron as a purely igneous product, in some instances poured out, but in others sublimed, from the interior of the earth. . . Where these ores occur in a state of almost absolute purity, in the form of vast irregular masses, occupying pre-existing depressions; or where the incumbent strata are metamorphosed and folded over them; or where they are traversed by long lines of ferruginous matter in the form of dykes—there can be little doubt that these ores have risen up in a plastic state from below.

"Where they are found impregnating metamorphic products, such as jasper, hornstone or chert, quartz, chlorite and talc slate, not only interposed between the laminæ, but intimately incorporated with the mass, giving it a banded structure, we regard it as the result of sublimation from the interior."

"When they are included in metamorphic strata, in the form of beds of variable width, with a conformable range and dip, and with minute particles of the associated rock mechanically mixed with the ore, we are disposed to regard them as the result of aqueous deposition, although the materials may have been derived from the ruins of purely igneous products" (p. 68.)

In *1857*, Sir William Logan and the Canadian geologists having recognized two distinct systems beneath the Potsdam sandstone, Mr. Whitney returned to the defence of the systemic unity of the sub-Silurian rocks, and of the system which he and Mr. Foster had proposed to receive them.* Mr. Whitney thinks this divergence of opinion is "due entirely to a different understanding of the origin and relations of the cupriferous formation of lake Superior and especially of that portion of it which belongs to the southern shore of the lake" (p. 306.) He proceeds accordingly, to establish the proposition that the cupriferous series of interbedded traps, conglomerates and sandstones are collectively the equivalent of the sandstone extending generally along the south shore. This being so, nothing remains between the cupriferous series and the granite except the indivisible series of rocks which Foster and Whitney had styled the Azoic system.

If we follow Mr. Logan, he says in effect, we must admit that the cupriferous belt lies unconformably beneath the sandstone.

"We must also admit that these cuperiferous rocks are identical in age with the series of quartz beds and jasper conglomerates displayed on the north shore of lake Huron, and hence called 'Huronian.' Therefore, according to Mr. Logan's views, since the cupriferous series of lake Superior rests unconformably on a still lower formation of shales, quartz rock, etc., the rocks of lake Huron must also do the same, although no such fact has been observed. Hence, we must recognize two systems beneath the Potsdam sandstone, one the Huronian, comprising the cupriferous rocks of lake Superior and the formations of the north shore of lake Huron, the other, the Laurentian, including all the rocks of Canada and the Northwest which we should designate by the term 'Azoic,' with the exception of those of lake Huron, as before indicated."

"The principal question to be settled then, is this: What are the relations of the cupriferous rocks of lake Superior? Do they

*J. D. Whitney, "Remarks on the Huronian and Laurentian systems of the Canada Geological Survey," *Amer. Jour. Sci.*, II, 305-394, May, 1857.

constitute a distinct system by themselves, or are they part and parcel of the Potsdam sandstone itself?" And this is the question which Mr. Whitney proceeds to answer affirmatively. Mr. Whitney's two main positions as against those of Sir William Logan, may be stated thus:

1. The cupriferous formation is *not* distinct from the Potsdam.
2. The Huronian rocks are *not* equivalent to the cupriferous.

In *1884*, professor Whitney again returned to a vindication of the integrity of the Azoic system.* In an extended and elaborate memoir, Messrs. Whitney and Wadsworth review all that had been written in America on rocks embraced under the Azoic system. They pursue the method of liberal quotation, in setting forth the views of the various writers, and accompany these by critical remarks. The authors find very little to commend in this literature, but discover many opportunities for caustic comment, seeming almost to forget that possibly the honest search for truth may not lie, precisely in an adoption of the views of the originators of the Azoic system. Still there is a good amount of justice in the following sentence, extracted from their "Resume:"

"We think that it is impossible for any unprejudiced worker in this department of science to peruse with care the preceding pages, and not feel obliged to admit that the geology of a large portion of this country, and especially that of Canada and New England, is in an almost hopeless state of confusion. We thing that it must have been made clear to the candid mind, that the geologist would find himself completely baffled, who should endeavor to obtain any definite knowledge of the real nature and order of succession of the rocks which cover so large a portion of the region in question, from the study of that which has been published with regard to them. We believe that we are justified in going still farther, and saying, that our chances of our having, at some future time, a clear understanding of the geological structure of northeastern North America would be decidedly improved, if all that has been written about it were at once struck out of existence" (pp. 519-520.)

All this tends to prove, as the authors think, that no real progress has been made in azoic geology since 1850. Their impressive resumé embraces the following positions: *First*, No evidence has been presented of the existence of life anterior to the advent of the primordial fauna of Barrande—that is, in those metamorphic rocks which were at first united in a system styled "Azoic." The supposed organism known as *Eozoön*, is only a peculiar arrange-

* *The Azoic System and its Proposed Subdivisions.* By J. D. Whitney and M. E. Wadsworth. *Bull. Mus. Comp.* Zoöl., Geological Series, vol. i, pp. xvi and 331-365.

ment of crystalline matter. Its organic nature was never consistently defended by Dawson and Carpenter. The segregated, vein-like character of the limestones in which it occurs in eastern Massachusetts, has been affirmed by Burbank, Perry and Dr. Wadsworth, and the final *coup de grace* has been administered by Dr. Möbius. The epitaph has been written by F. Römer and Zittel. As to the organic origin of the crystalline *limestones*, there is nothing whatever to prove it, while the presene of calcite and calcitic formations in metalliferous veins, and in dykes and amygdaloids is sufficient proof that the existence of a limestone does not necessarily imply conditions compatible with organization. *Graphite*, too, instead of being a derivative of vegetable substances is found in the presence of indications of intense heat, and has never been found in such situation as to justify the inference that it resulted from the transformation of coal. As to the origin of masses of *magnetic and specular oxides of iron*, there is nothing in the laws of chemistry to forbid their eruptive nature, while the distribution of iron in meteorites and on the earth, and the evidences touching the mineral nature of the earth's interior, all tend to show the probability that the iron of the earliest times was connected with the agency of heat rather than of organization.

Secondly, As to the admissibility of a subdivision of the azoic rocks, the authors maintain that no adequate ground has yet been presented. They moreover, preclude the possibility of such ground by laying down the canon that observed successions of life are the only justification of a chronological arrangement of rocks. Of course, no successions of life are possible where no life exists. To pronounce a series azoic and demand the application of the palæontological dogma, is to move the previous question without debate. Whether there are or may be, good grounds other than palæontological, for a successional arrangement of terranes, is a question which will be considered in the sequel of this memoir. The mineralogical and lithological bases of various proposed divisions of the Azoic are examined, and besides their exclusion at the threshold by the canon laid down, are represented as inherently conflicting and invalid. Finally, to illustrate the misleading character of mineralogical criteria, they push the principle *in absurdum* by proposing ironically, a division of the Azoic into twelve systems based on predominant mineral characteristics.

This memoir, though characterized by a spirit of dogmatism and wholesale contempt of contemporary research, justified only by the assumption of infallibility in the work of its authors, is still, a masterly review and a forceful argument, challenging serious reconsideration of the evidences on which many of our recent judgments have been based.

T. STERRY HUNT.

Dr. Hunt's writings on pre-Silurian rocks have been voluminous and long continued. His utterances are largely of an inferential and deductive character, based on the field-observations and judgments of others, backed, however, by numerous personal reconnoissances. He appears to have been to some extent, the expositor and commentator and public representative of the Canadian survey. The value of his work in the aggregate — especially his chemical and mineralogical work, is great. He has made a durable impression on the science of his day. But his proper geological utterances, while always learned and sagacious, have sometimes possessed doubtful value. From lack of close adherence to observations made by himself, and from too much readiness to give utterance to the intuitions of the moment, he has fallen into occasional self-inconsistencies, and many conflicts with his fellow workers in geology. Partly for such reasons, I shall not follow out in detail the varying utterances which during a long life, he has placed on record.

1855. Dr. Hunt appears to have been the first to employ the term "Huronian" in its application to a series of rocks. In "A Sketch of the Geology of Canada," speaking of the rocks on the north shore of lake Huron, then recently studied by Mr. Murray, he says:

"As these rocks underlie those of the Silurian system, and have not as yet, afforded any fossils, they may probably be referred to the Cambrian system (Lower Cambrian of Sedgwick). . . This *Huronian formation* is known for a distance of about 150 leagues upon lakes Huron and Superior."*

1858. Dr. Hunt suggested evidences of the contemporary existence of organic life in the limestones, graphite and iron ores of the Laurentian.†

On the discovery of *Eozoön* so called, he discussed the mineral-

* *Canada at the Universal Exposition* of 1855, pp. 427, 428. [*Esquisse géologique*, pp. 28, 33, 1855]. Mr. Murray, as we have seen, had already employed the term *Huronian series*, in his report for 1855; but that was not printed till 1857. Neither he nor Hunt employed the term deliberately, as the designation of a well comprehended system of rocks, but only to express the geographical position of certain rocks referred to. In 1857, Sir William Logan made formal announcement to the American Association, that the term *Huronian* had been adopted. See *anté*, pp. 123, 124.

†*Quar. Jour. Geol. Soc.*, xv, 493.

ogical relations of the object, and gave the name *loganite* to a supposed new mineral form.*

In the *Esquisse géologique du Canada,*† Dr. Hunt described the Laurentian system as embracing two distinct series, one resting *discordantly* on the other. These he denominated Lower Laurentian and Upper Laurentian or Labradorian (afterward called by him Norian).

The so-called "Hastings series" was first brought into notice in 1852-3 by Mr. Murray (pp. 103-108), and in the discussion of these rocks, Dr. Hunt frequently participated. In *1863*, he gave analyses of the limestones (*Rep.*, 1863, pp, 592-3). In *1867*, he stated that the Hastings series reposed in *concordant stratification* on the Laurentian gneiss, but that the Upper Laurentian or Labradorian, rested *unconformably*, not only on the Lower Laurentian, but also on the Hastings series.‡

In *1869*, he identified as Laurentian,§ "the great gneissic and hornblendic formation stretching through" the northeastern portion of Massachusetts, and inclosing crystalline limestones, and on the ground of their age, promoted successfully the search for *Eozoön canadense*.

In *1870*, his attention was again turned to the geology of eastern New England,‖ and he recorded the conclusion that, "In fact, the schists and gneisses of the White Mountains are clearly distinct, lithologically, from the Laurentian and the Huronian, as well as from the crystalline rocks of the Green Mountains, and from the fossiliferous Upper Silurian strata, which lie at the southwestern base of the Canadian prolongation of the latter." (p. 84.). Turning then, to the lithological characters of the "Hastings series" in Canada, he says Mr. Vennor has shown that "it rests unconformably upon the old Laurentian gneiss, while it is at the same time overlaid by the horizontal limestones of the Trenton group. This intermediate series which attains a thickness of several thousand feet, is terminated by calcareo-micaceous schists, in which *Eozoön canadense* has been found, both in Madoc and Tudor." (p. 85.) He then summarizes Mr. Murray's observations in Newfoundland in 1866 and recognizes there a mass of rocks "immediately succeeding the Laurentian," and concludes:

"From these investigations of Mr. Murray, we learn that between the Laurentian and the Quebec group, there exists a series

**Geology of Canada*, 1863, p. 490.

†*Paris Exhibition of 1867*, p. 10.

‡*Esquisse géologique* pp. 5, 6.

§On Laurentian rocks in eastern Massachusetts, *Am. Jour. Sci.*, II xlix, 75-78.

‖"On the Geology of Eastern New England," *Amer. Jour. Sci.* II, l, 83-90.

of several thousand feet of strata, including soft, bluish-gray mica slates and micaceous limestones belonging to the Potsdam group; besides a great mass of whitish granitoid mica slates whose relation to the Potsdam is still uncertain. To the whole of these we may perhaps give the provisional name of the *Terranovan series*, in allusion to the name of Newfoundland." (p. 87.)

The Terranovan series therefore occupies a portion of the interval in which lies also the "Norian" and the "Huronian," and it overlaps the Potsdam. To this he referred the White Mountain rocks, as well as certain rocks in New Brunswick.

In *1868*, he prepared a memoir on the mineralogy of the "Laurentian limestones of North America*" in which he wrote:

"In the county of Hastings, in the Province of Ontario, not less than 21,000 feet of strata, consisting of crystalline schists, limestone and diorite are found resting *conformably* upon Laurentian gneiss." (p. 48.)

In a postscript (p. 98,) he states:

"More recent researches by the Geological Survey of Canada have shown that the rocks of Hastings county, Ontario, noticed on page 48, rest *unconformably* upon the Laurentian, and belong to one, and possibly two, distinct systems. The upper and larger portion consists in great part, of mica schist and micaceous limestones, while at the base are great masses of dioritic and hornblendic schists, with iron ore, posssibly of Huronian age."

In *1873*, he was reported as follows:

"As regards the *Norian*, which had been once joined to the Laurentian, he had elsewhere shown that we had reason for suspecting that it might be more recent than the Huronian, and possibly than the *Montalban*, a conclusion which appeared to be confirmed by the facts made known by Hitchcock."†

In *1875*, he returned to a study of the White mountains, or Montalban series, which he had already identified with the Hastings series. He said:

"These ancient rocks are also largely represented in Hastings county, Ontario, where they occupy a position between the Laurentian [i. e. Lower Laurentian] and the fossiliferous limestones of the Trenton group, and are the equivalents of similar limestones and micaceous quartzytes in Berkshire county."‡

In *1878*, Dr. Hunt referred the limestones of the Hastings series

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**Twenty-first Annual Report of the Regents of the University of the State of New York*, Apepndix, pp. 47-98.

†*Proc. Bost. Soc. Nat. Hist.*, 1873, xv, 310.

‡*Proc. Soc. Bost. Nat. Hist.*, 1875, xvii, 509.

to the lower Taconic (Taconian).* In his "Chemical and Geological Essays," the Hastings limestones and slates are said to lie between the Huronian and Trenton.

In *1878*, he prepared a synopsis † of his views on the classification of Eozoic (Archæan, Azoic) rocks. Their divisions were distributed as follows:

1*d*. MONTALBAN. Named in 1872[=Terranovan], well displayed in the White Mountains, and occupying large areas in New England and southwestward; a great mass of crystalline schists. Gneisses distinguished from those of the Laurentian by being finer grained and having white feldspar. They are less firm and more tender, often containing silvery mica, and pass into coarser mica schists. This series contains granular olivine rocks [*dunite*] often accompanied by enstatite [*saxonite* of Wadsworth].

1*c*. HURONIAN. Named in 1855, more or less schistose, crystalline rocks, resting unconformably on the Laurentian. "The Green mountain series." Contain jaspery petrosilex, becoming porphyritic by the presence of feldspar and of quartz in a compact base, sometimes schistose and finely laminated. Contain basally, chloritic schists altered from diabases. [The description applies to the lake Superior pseudo-Huronian, not to the original lake Huron Huronian.]

1*b*. NORIAN. The upper portion of the Laurentian series on the Ottawa river. A distinct terrane, resting unconformably upon the gneisses and crystalline limestones of the Laurentian. The former Upper Laurentian or Labradorian. Consists chiefly of anorthic [triclinic] feldspar, sometimes almost without admixture; sometimes accompanied by small portions of hornblende, of pyroxene or of hypersthene (hypersthenite or hyperite). Fine or coarse. Colors white, pale bluish or greenish, dark lavender, smoke-blue or nearly black. Titaniferous iron occurs in great beds.

1*a*. LAURENTIAN. Named in 1854, prevailingly a strong, massive gneiss, reddish or grayish, sparingly micaceous, very often hornblendic. The crystalline schists absent. Crystalline limestones present, often associated with beds of quartz. Masses of magnetite. Beneath these (the *Grenville series*) a great mass of granitoid gneiss without limestone (the *Ottawa gneiss*).

Above the Montalban is placed the TACONIAN (=Lower Taconic); QUEBEC group (=Upper Taconic or Cambrian), (pp. 10, 11, 12, 13, 21).

**Proc. Bost. Soc. Nat. Hist.*, 1878, xix, 278; preface to second edition of *Chem. and Geol. Essays*, pp. xxii, xxvi.

†*The Geologists' Traveling Handbook.* By Dr. James Macfarlane. New York, 1879. It was circulated before the close of 1878.

The following is Dr Hunt's view of the taxonomy of the lower rocks in his Pennsylvania Report:*

8. SILURO-CAMBRIAN. Upper Cambrian of Sedgwick. Part of Lower Silurian of Murchison, and the Matinal of Rogers, in part.

7. CAMBRIAN. The Lower and Middle Cambrian of Sedgwick, and the Lower and Upper Cambrian of Hicks; being the Upper Taconic of Emmons, and the Quebec group of Logan: or the Primordial Silurian, and part of the Lower Silurian of Murchison. [Upper Copper-bearing rocks of Logan.]

6. KEWEENIAN. The Copper-bearing series of Lake Superior, found in the same geological interval as the Taconian, but not identified with it.

5. TACONIAN. The Lower Taconic of Emmons, or the "Hastings series," including a part of the Primal, Auroral and Matinal divisions of Rogers; and constituting with the Montalban, what he had once called Terranovan.

4. MONTALBAN. The White Mountain or Mica schist series. [Terranovan in part.]

3. HURONIAN. The Green Mountain series, or altered Quebec group of Logan. [Lower Copper-bearing rocks of Logan.]

2. NORIAN. The Labradorian or Upper Laurentian of Logan.

1. LAURENTIAN.

  b. *Grenville series.* With limestones. Supposed unconformable with the next.

  a. *Ottawa gneiss.* Without limestones. (pp. 215-242.)

In *1879*, the Norian was said by Dr. Hunt to rest *unconformably* upon the gneisses and crystalline limestones of the Laurentian, and held to be older than the Huronian. The Huronian was also said to rest *unconformably* on the Laurentian on the north shores of lakes Huron and Superior.

In *1886*,† Dr. Hunt's conception of the succession of the Azoic Rocks was freshly set forth with a result of which a brief abstract is as follows:

SILURIAN.

ORDOVICIAN.

CAMBRIAN.

KEWEENIAN. Upper division of Upper Copper-bearing series.

**Special Report on the Trap Dykes and Azoic Rocks of southeastern Pennsylvania.* By T. Sterry Hunt. Part I. Historical Introduction. Harrisburg, 1878. pp. 253. [Being E of the series of Survey Reports. This Report is dated 1875, though the Preface bears date 1878.]

†*Mineral Physiology and Physiography*, a second series of Chemical and Geological Essays. with a General Introduction. Boston, 1886, 8vo, pp. xvii plus 710.

TACONIAN. Lower division of Upper Copper-bearing series. Quebec group of Logan.

MONTALBAN.

HURONIAN. ?*Pebidian* of Hicks.

ARVONIAN. (Formerly part of Huronian.) Petrosilex series,— jaspers and porphyry. *Hälleflinta*, Sweden. *Arvonian* of Hicks.

NORIAN. (Formerly Upper Laurentian or Labradorian.)

LAURENTIAN. (Former Lower Laurentian.) ?*Lewisian* of Murch.

Grenville series. Typical Laurentian (Former Middle Laurentian.) *Dimetian* of Hicks.

Ottawa gneiss.*

Dr. Hunt has always been resolutely opposed to the identification of the Animike Series with the proper Huronian. The following passage, among many others is explicit:

"The fact that the Taconian or Animike series in Northern Michigan, rests sometimes upon the Granitoid or Gneissic group, sometimes upon the Dioritic group, of Rominger, and elsewhere upon a mica schist series having the characters of the Montalban, goes far to show its stratigraphical distinctness from all three of these. Its separation from the Dioritic group was early noticed by Logan, when he described the unconformable superposition of this series (the lower division of his Upper Copper-bearing series) on the ancient greenstone (Huronian) series, and the presence of portions of this in the basal conglomerates of the latter. There are, however, as I have elsewhere noticed (*Azoic Rocks*, p. 202,) certain mineralogical resemblances between the Taconian and the softer and more schistose beds of the Huronian, with which they were confounded by Murray at more than one locality along the north shore of Lake Superior. Hence, after visiting the Marquette district in 1861, he did not hesitate to call the iron-bearing series of that region Huronian; a designation adopted by the Geological Survey of Canada. In this he was followed by J. P. Kimball in his study of the Marquette iron ores in 1865, by Hermann Credner in 1869, by T. B. Brooks in 1873 and again by Irving in 1883. All of these include the two series under the common name of Huronian, and the estimates of the thickness of the Huronian have

*The following references may be made to opinions of Dr. Hunt on the geology of New Brunswick: Hunt: *Geology of Canada*, 1866, pp. 235, 236; *Amer. Jour. Sci.*, II, 1870, 1, p 89 (Compare *Proc. Amer. Assoc.*, 1871, p. 33;) *Azoic rocks*, 1878, 181, 188, 189; *Proc. Amer Assoc.*, 1873, B, 116, 117; 1879, 285-7; *Amer, Jour. Sci.*, 1880, III., xix, 273-5; *Boston Proc.*, 1875 xvii, 509; *id.*, xix, 278; Preface, 2d. ed. *Chemical and Geological Essays*, p. xxix; *Mineral. Physiology and Physiography*, pp. 407-8, 572-4.

been based upon that of the two united. The distinctness of the underlying Dioritic group with its serpentines and chloritic rocks, which together constitute the Huronian or *pietre verdi*—alike from the older granitoid and gneissic group, from the mica-schist or Montalban group and from the great overlying Animike or Taconian system, including the quartzites, marbles, iron-ores and argillites, is however, manifest. The succession is thus brought into complete accordance with that which is found in many parts of the Appalachians, as well as in southern Europe, as is pointed out in part iv of Essay X."*

Dr. Hunt, in other passages, recognizes the presence of the Animike (Taconian) or true Huronian in the Upper Peninsula of Michigan. He writes:

"Resting in some cases upon this group† and in others upon the granitoid rocks is a great system divided in ascending order by Rominger, in 1880, into a Quartzite group (which includes a marble series,) an Iron-ore group, and an Arenaceous-slate group, all of which appear closely connected. The system comprises heavy beds of quartzite, often schistose and with conglomerates, interstratified and overlaid by argillites of various colors, with graphitic, hydro-micaceous or sericitic slates, beds of jasper, of hæmatite and magnetite, either pure or disseminated, and, in the upper portion, limonite and siderite. The limestones form in the upper part of the quartzite division, great masses of white crystalline marble, sometimes with mica and tremolite and sahlite; at other times they are reddish or dull and compact. The iron ores appear to be in two horizons, one below and one above a great body of limestone. To the latter are referred the ores of the Gogebic and Menominee districts, and to the former, those of Marquette and Felch mountain, with which those of Vermilion lake in Minnesota, appear to be identical. The argillites which overlie the latter are those seen in the St. Louis river and at Thompson, Minnesota, which are by Rominger compared with argillites at L'Anse and Huron bay."‡

George F. Matthew and Associates in New Brunswick.

Several different Canadian geologists have participated in the investigation of the geology of the maritime provinces of British North America. The pioneer among them was the present Sir William Dawson, whose special studies for the greater part, have

*Mineral Physiology, 581-2.

†The Dioritic group of Rominger.

‡Mineral Physiology, pp. 579-80. The writer has elsewhere recorded his independent recognition of the existence of two discordant systems in the Marquette Iron region—*Sixteenth Annu. Rep. Minn.*, pp. 178-9, 185.

Development of Opinion on the Pre-Carboniferous Geology of New Brunswick.

J. W. Dawson.	Geo. F. Matthew, 1863.	Geo. F. Matthew, 1865.	Bailey & Matthew, 1865.	Bailey & Matthew, '70-71.	Matthew, 1876-7.	Bailey & Matthew, '77-78.	Bailey, 1880.	Bailey, Matthew & Ells, 1878-9.
1855 Silurian. 1861 Devonian.	DEVONIAN. Mispec Gr. (No. 1 of Dawson) 1800 ft. b. Fine slates and grits. a. Coarse conglomerate. Little River Group,[1] (2 and 3 Daw.) b. Cordaite shales, 2,400 ft. a. Dadoxylon sandstone, 2,800 ft. Bloomsbury group (4 of Dawson). b. Fine red clay slate and reddish gray cong. 2,000 ft. a. Erupted beds, 2,000 ft.	DEVONIAN.[2] [3]{ Mispec. Little River. Bloomsbury. Lower Devonian.	Mispec. Little River. { Cordaite shales. Dadoxylon sandst. Bloomsbury.[5] Kingston group,[6] (part).	Mispec cong. Cordaite shales. Dadoxylon sandstone. Bloomsbury.	Mispec cong. Cordaite shales. Dadoxylon sands.			
1862 Devonian.	St. John group (5 and 6 in part of Daw.), 3,000 ft.	UPPER SILURIAN.	Dalhousie limestone. Kingston.	Flags and shales.	Upper Kingston.[12]	Kingston series.[13]	Certain feldspar porphyries.	Silurian. Cambro-Silurian. Cambrian or Primordial.
Silurian.(?)	Several zones of shales alternating with gray slates and thin sandstones. Lingulæ, etc.	LOWER SILURIAN. St. John.[4]	St. John (Potsdam and Quebec) Fossils.	St. John or Arcadian. Upper Coldbrook.	Lower Kingston. St. John.	Cambrian or Primordial or St. John gr.	Upper Kingston gr.	
1868 1878 Agrees with Matthew & Bailey.	Coldbrook gr. (6 of Dawson in part) 3,000 ft. c. Reddish cong. and grit. b. Red slaty cong. and sandy shales. a. Greenish slate.	HURONIAN. Coldbrook. Upper. Lower.	Coldbrook.[7]	Lower Coldbrook. Coastal group.[9] Kingston gr.[10]=? Mascarene gr.[11]	Bloomsbury. Coldbrook.	Schistose, chloritic and micaceous gr., coastal gr. Felsite-petrosilex (Coldbrook).	Lower Kingston. Coastal gr. Talc schists, congl. limestone. Coldbrook gr. Felistic.[14] etc.	Kingston Division:[16] Felsite, schist, slate cong., felsite cong. and clay slate. Coastal Division: Chloritic, felspathic and talcose; schistose cong. Coldbrook Division: Petrosilex and felsite, agglomerates, diorites, etc.
	Portland series (7 and 8 Dawson). Granite, syenite, gneiss, mica schist, limestone, clay slates. Plant-fragments in upper beds.	LAURENTIAN. Portland.	Portland.[8]	Laurentian—(including Labradorian.)	Coastal? Portland.	Lime-stones and dolomites, mica schists. Syenitic, feldspathic and gneissic.	Finer gneiss, quartzites =?Hastings. Coarse gneiss.[15]	Syenite and gneiss, quartzite, felsite, limestone, mica and felsite schists. Syenite-gneiss and felsite.

1. Certain rocks afterward separated from this group under the name of Coastal were placed in the above group as upper Devonian, because they overlie the Dadoxylon sandstone conformably (or nearly so), and underlie the Carboniferous unconformably, while they partake of the flexures of the Devonian series.

2. The systemic names in this column apply to all the succeeding columns.

3. These three groups rest unconformably on the Laurentian, Huronian and Silurian, and were regarded as middle and upper Devonian.

4. No unconformability between this group and the Huronian.

5. Entirely conformable with the Little River and Mispec groups; not entirely so with the St. John.

6. "Made Upper Silurian? on lithological and stratigraphical grounds."

7. "Probably Huronian, both over and under-lying the St. John group."

8. Assigned to the Laurentian on lithological and stratigraphical grounds. Almost entirely conformable to the over-lying Upper Devonian.

9. Overlying Upper Silurian and Lower Devonian, but, from its lithological characters placed in the Huronian.

10. Contains intercalated Upper Silurian strata; but Coastal overlies them.

11. The Mascarene series was referred to the Upper Silurian in Rep. of 1874-5, pp. 84-9.

12. Contains pebbles derived from the St. John group.

13. Placed on supposed palæontological evidence.

14. Between these two "there is, not unfrequently, evidence of at least a partial unconformability."

15. On the north of the main granitic axis, numerous blocks, or what appear to have been detached masses of gneiss or sandstone, are completely surrounded by, or included in, the granite in such a way as to look like a coarse conglomerate."—Proc. Amer. Assoc., 1880, p. 429.

16. These rocks should be compared with the Animike of Lake Superior.

been palæontological.* Among those who have contributed important original observations and have studied especially the oldest rocks, are George F. Matthew, L. W. Bailey and R. W. Ells. This portion of the continent presents great geological difficulties, and the interpretations of the phenomena have been very diverse. The differences, however, have been rather of local than of geognostic significance; and it is therefore not intended to trace the historical development of opinion into detail. Following Sir William Dawson, Mr. George F. Matthew, in 1863, presented the results of a well elaborated series of observations on the geology of St. John county, New Brunswick† and proposed an arrangement of the rocks which will be reproduced synoptically in the following table.‡

The table which follows is compiled from papers cited in this connection.

Charles H. Hitchcock.

Professor C. H. Hitchcock's survey in the state of Maine did not lead him into researches possessing any important bearing on the development of American opinion respecting the nature and origin of the older rocks. The official character of his connection with the Vermont survey, the first volume of the final report of which was published in 1861, though prepared in 1859, was as chemist of the survey. But, provision for the chemical work being inadequate, professor Hitchcock devoted much attention to geological investigations. Among these was the preparation of a chapter on "Azoic Rocks" and contributions on "Steatite and Serpentine" and "Saccharoid Azoic Limestone."§

*_Acadian Geology. The Geological Structure, Organic Remains and Mineral Resources of Nova Scotia, New Brunswick and Prince Edward's Island._ First edition, 1855, 2d, 1868 (with information posted to date), 3d, 1878. For other recorded opinions of Sir William Dawson, see _Can. Nat. and Geol._, 1861, I, vi, 164; _Quar. Jour. Geol. Soc._, 1862, xviii, 303. Sir W. E. Logan made a reconnoissance of the Bonaventure formation in 1843; and Dr. Abraham Gesner made a report to the New Brunswick government at nearly the same date.

†_Canadian Naturalist and Geologist_, viii, 241-260, Aug. 1863. For later views see _Quar. Jour. Geol. Soc._, 1865, xxi, 422-434.

‡The later studies of Messrs. Matthew, Bailey, Hartt, Ells and others may be consulted as follows: Bailey: _Canadian Naturalist_, 1864, 81-97 (a rapid reconnoissance); Bailey, Matthew and Hartt: _Observations on the Geology of Southern New Brunswick_, 1865: H. Y. Hind: _Prelim. Report on the Geol. of New Brunswick_, 1865; Bailey and Matthew: _Proc. Amer. Assoc._, 1864, xviii, 179-195 (revised to April, 1870); Bailey and Matthew: _Geol. of Can. Report of Progress_, 1870-71, 13-240 (proposing numerous changes on recommendation of Dr. Hunt); Matthew: _Report_, 1874-5, pp. 84-9; _Report_ for 1876-7, 322-350; Hugh Fletcher: _Same Report_, 405-426; R. W. Ells: _Rep. Prog._ for 1877-8, D., pp. 1-12; L. W. Bailey: _Rep._ 1877-8, DD., pp. 1-34; G. F. Matthew: _Same Rep._, E, pp. 1-6; Bailey, Matthew and Ells: _Rep._, 1878-9, D., pp. 1-26; R. W. Ells: _Rep._, 1879-80, D., pp. 30-42; _Rep._, 1880-82, D., pp. 17-19: Bailey: _Proc. Amer. Assoc._, 1880, 416, 417: _Can. Rep._, 1882-4, E., pp. 31-34; A. P. Low: _Rep._, 1882-4, F., pp. 16-20; R. W. Ells: _Rep._, 1885, E. pp. 54-63. Dr. T. S. Hunt's recorded opinions have been already referred to, _Ante._ p. 150

§_Geology of Vermont_, I, pp. 452-474 and 533-558.

In consonance with views generally prevailing at the time, he expresses the opinion respecting the azoic rocks, that "stratification and lamination appear to have been produced by original deposition in water." Speaking of the difficulty of distinguishing, in some cases, between the lines of sedimentary structure and cleavage and foliation, he says: "We have not attempted it [distinction of cleavage] to much extent in the slates of Vermont; still less have we tried to draw a line of distinction between the foliation of the schists and stratification; for this is a still more difficult work. Hence the strikes and dips which we shall give are those of foliation and cleavage. But we believe that these usually correspond essentially with the stratification. In the fossiliferous clay-slates of the western part of the State, as well as in the limestones, we not unfrequently have found the cleavage planes making quite an angle with those of the original deposition; but in all those belts of slate interstratified with the more thoroughly metamorphosed schists, the two seem usually coincident." (p. 452.)

No attempt is made to give the azoic rocks either a systemic, a geognostic or a chronological arrangement. Fifteen species are enumerated and lithologically described. Five and a half quarto pages are devoted to a catalogue of isolated instances of strike and dip, though very little attempt is made to correlate them in a general system of structure. It is stated however, that three distinguishable ranges of gneiss traverse the state: the Green mountain range, the middle range and the Connecticut river range. The first of these is thought a continuation of the Hoosac mountain range—the gneiss of the Green mountains resulting from the accession of feldspar to the mica schist of Massachusetts, though often, in Vermont, passing again into mica schist. Of some of the gneiss of the range along the Winooski, he says "it resembles sandstone—the crystals of feldspar being rounded like large grains of sand. (p. 465.) The middle range is less extensive and more distinctly gneissic. Eastward it graduates into mica schist. The gneissic range near the Connecticut river consists only of three patches."

The unessential character of the recognized distinction between gneiss and mica schist, as indicated in the transitions along the strike, mentioned above, is emphasized by further statements. "Those layers of the rocks" he says, "on both sides of the mountain, which all would regard as gneiss, are generally interstratified with other layers of mica or talcose schist and quartz; and the judgment of good observers would differ about the line where the gneiss predominates over the schists." "Also, as we pass northerly along the line of strike [of the Green mountain range] along the eastern margin, the gneiss is rapidly succeeded by mica and talcose schists..** We incline to the opinion, however, that a narrow belt of Green mountain gneiss does extend across the whole State of Vermont.** We have expressed the opinion in another place, that gneiss, mica and talcose schist, and even some beds of quartz, may be only metamorphic varieties of the same original formation." (p. 470.)

Of hornblende rock he says: "It is found associated with gneiss and clay-slate in positions much like dikes, as well as in regular beds." Referring to the opinion expressed by MacCulloch, that hornblende rock and hornblende schist may result from the metamorphism of clay-slate, professor Hitchcock states that Bischof has shown it possible that "even in lava, the hornblende [sometimes present] was not formed at the time of the protrusion of the lava, but subsequently in the wet way; and the associations of hornblende schist forbid the idea that it was a volcanic product."

In reference to steatite and serpentine, professor Hitchcock states that "there are at least sixty beds of steatite in Vermont, and twenty-five beds of serpentine. The aggregate of serpentine is more than double that of steatite. Regarding the steatite and serpentine rocks as of one age in each range, he concludes that there are four ranges, and that these are of different ages.

As to origin, he regards serpentine as originally stratified, referring to its conformability with the foliation of the rocks which embrace it. There is no protruded serpentine in Vermont. Steatite, probably, had a similar origin. He believes in the change of "some beds of hornblende schist and diorite or greenstone, into serpentine." (p. 554.)

In general connection with the subject of metamorphism, professor Hitchcock makes the following just remarks:

"The distinction between stratified and unstratified rocks has been usually regarded as one of the most trenchant and reliable in the science of geology. And so long as it was considered a certain fact that the stratified rocks were exclusively deposited by water, and the unstratified all resulted by dry heat, it is not strange that geologists should have looked upon the line between the two classes as very distinct and recognizable. But now that it is so generally admitted that hot water has been the most efficient agent in metamorphosing the stratified rocks, and converting some of them into the unstratified, we can see how the distinction between them should often be very obscure and uncertain. Such is certainly the case with serpentine and dolomite, both of which are sometimes stratified and sometimes unstratified. We are apprehensive that some other system of classification must be adopted, to include such rock and also such varieties of gneiss, and even some of the schists." (pp. 554-5.)

The results of the studies of professor Hitchcock and his collaborators in the geology of New Hampshire are embraced in three massive royal octavo volumes.* They embody a vast amount of faithfully elaborated information in a region of extreme difficulty, which had hitherto received vastly less geological than mineralogical study. The state presented extraordinary difficulties, arising, *first*, from the absence of organic remains, those time-marks by which the geologist is able to recognize his position in the progress of æons past, and *secondly*, from the destruction of the traces of superposition by those orogenic disturbances which almost wholly obliterated the records originally made; and *finally*, by the metamorphism which had not only transformed the aspects and constitution of rock-masses, but had effected alterations of such varying nature and degree as to defy identification by the usual resemblances. In this trackless geological wilderness the geologist entered, meagrely equipped for his great work, and reported to the state and to the world the progress made from year to year, until lapse of time and exhaustion of means rendered it imperative to pronounce final verdicts. As a matter of obvious necessity, the geological conception underwent revision and augmentation with every season's addition of knowledge. But it was a peculiar merit of professor Hitchcock's advancing work that he was ever ready to announce the shape which his conception of the State's geological structure and history had attained after the latest acquisitions of observed fact. A less unsuspicious mind—perhaps it might be said, a more judicious method, would have enforced more reserve. The difference would be that a more prudent investigator would have reached thoughts not more mature and final, but would have held his "best thoughts" in reserve; while Hitchcock freely shared them with the public. It has been found possible to cast censure on professor Hitchcock that his annual announcements of status reached were so conflicting and changeful; but a just and generous view must regard them simply as marks of the progress of ideas, and encouragments to all who may be grappling with equal difficulties.

***Geology of New Hampshire.* By C. H. Hitchcock, J. H. Huntington, Warren Upham and G. W. Hawes. Volume i, containing Part I, (1874) "Physical Geography," 668pp; Volume ii, (1877,) containing Part II, "Stratigraphical Geology." 685pp; Volume iii, (1878), containing Part III, "Surface Geology," Part IV, "Mineralogy and Lithology," Part V. "Economic Geology."

It occurs to the writer that it may be best to present first, the series of provisional conclusions announced by professor Hitchcock in the progress of his work. These are taken substantially as compiled by Whitney and Wadsworth—the order of arrangement being inverted, in conformity with the method of this memoir.*

ANNUAL REPORTS, 1860-1872.

First Annual Report, 1869.

Upper Schists.
Quebec Group.
  Auriferous Conglomerate.
  Clay Slate.
  Copper Belt.
  Lower (mostly green) Schists.
  Staurolite Schists.
White Mountain series (Gneissic, Granitic)

2d Annual Report, 1870.

Clay Slates.
Calciferous Mica Schist.
Coös Group.
Lower Silurian.
  Quebec Group.
  Merrimac Group.
Common Granite.
Porphyritic Granite.
Laurentian (?) Exeter Syenites.
Eozoic (White Mountain or Gneissic Series).
  Soapstones.
  Limestones.
  Quartzyte.
  Porphyritic Granite.
  Syenite.
  Granite.
  Chiastolite Slates.
  Andalusite Gneiss.
  Feldspathic Mica Schist.
  Granitic Gneiss.
  Ferruginous Gneiss.
  Normal Gneiss.

3d Annual Report 1871.

Coös Group.
Clay Slate and Quartzytes.
Laurentian (?).
  Norian.
  Brecciated Granite.
  Trachytic Granite.
  Common Granite.
  Andalusite Gneiss (White Mountain Gneiss),
  Gneiss.
  Bethlehem Gneiss.
  Porphyritic Gneiss.

4th Annual Report, 1872.

Division 3.

Andalusite Slates of the Coös Group.
Mica Schist.
Quartzyte.
White Mountain Series.
  Andalusite Gneiss, Ordinary and Imperfect Gneiss, the Concord and Fitzwilliam Granite. Soapstone and Limestone.
Granite Gneiss.
Laurentian.
  Granite and Porphyritic Gneiss.

Division 2.

Norian (Pemigewasset Basin).
  Green Granite and Syenite.
  Four Series of Compact Feldspar.
  Spotted Granite.
  Common Granite.
Laurentian.
  Franconia Breccia.
  White Mountain or Andalusite Gneiss.
  Bethlehem and Berlin Gneiss.
  Porphyritic Gneiss and Granite.

Division 1.

Helderberg.
Cambrian.
  Coös Group.
    Decomposing Slates, Dikes.
    Calciferous Mica Schist.
    Mica and Argillaceous Schists.
    Quartzytes, Staurolite Schists.
  Auriferous Clay Slates.
Huronian.
  Conglomerates and Quartzytes.
  Hydromica and Talcose Schist.

PROC. AMER. ASSOC. ADV. OF SCI., 1872. xxi, 134, 135, 150.

II. Palæozoic.
    Clay Slates.
    Helderberg Limestones.
I. Eozoic.
    5. Older Cambrian.
      Merrimac Group and probably Calciferous Mica Schist of the Vermont survey.
      Coös Group.
    4. Huronian.
      The Talcose Schist Series.
    3. Exeter Syenites.
    2. Norian.
      f. Red compact and Crystalline Orthoclase Felsite.
      e. Dark compact Orthoclase Felsite.

*Bull. Mus. Comp. Zool., Vol. vii., p. 396.

d. Compact Labradorite Felsite.
c. Ossipyte.
b. Trachytic Granite.
a. Common Granite.

1. Laurentian.
f. Range of Gneiss between Whitefield and Milan, considerably Hornblendic.
e. Gneiss on both flanks of the Porphyritic variety in the south part of the State, carrying the Concord and Fitzwilliam Granite, and is probably the Beryl-bearing Series.
d. Gneiss of Lake Winnipiseogee Basin.
c. Bethlehem or Talcose Gneiss.
b. White Mountain Series or Andalusite Gneiss.
a. Porphyritic Gneiss.

PROC. BOSTON SOC. NAT. HIST., 1873.
xv, 304-309.

V. Palæozoic.
B. Clay Slates.
A. Helderberg Limestone.
IV. Mostly Cambrian (?).
F. Mount Mote Conglomerates.
E. Green Granite.
D. Clay Slates.
C. Coös Group.
B. Merrimac Group.
A. Mica Schists of Rockingham County.
III. Huronian.
Feldspar and Talc.
Whitish Schists.
Green Schists.
Talcose and Auriferous Conglomerates.
II. Laurentian.
H. Syenites of Exeter and Tripyramid.
G. Reddish compact Orthoclase.
F. Red compact Orthoclase.
E. Dark compact Orthoclase.
D. Dark compact Labradorite.
C. Ossipyte.
B. Spotted Granite.
A. Common Granite of the White Mountains.
I. Laurentian (?).
C. White Mountain or Andalusite Gneiss.
B. Bethlehem Gneiss.
A. Porphyritic Gneiss.

PROC. AMER. ASSOC. ADV. SCI., 1873.
xxii, 120-131.

Winnipiseogee Lake.

Eozoic.
Mica Schist.
Eruptive Syenite.
Labradorian.
Felsites or Compact Feldspars.
Eruptive Granites of the Ossipee Mountains.
Laurentian (?).
White Mountain Series.
Winnipiseogee Lake Gneiss Formation.
Porphyritic Gneiss or Granite.

GEOLOGY OF NEW HAMPSHIRE, 1874
i, 506-539.

Helderberg Period.
Mica Schist Period.
Coös Group.
Cambrian Auriferous Clay Slates.
Merrimac Group.
Rockingham Mica Schist.
Eozoic.
Huronian.
Conglomerate.
Serpentine with Silicious Schist, and Dolomite and Soapstone.
Copper and Iron Beds.
Labrador.
Eruptive Syenite.
Fine Sedimentary Deposits.
Chocorua Granite.
Albany Granite.
Conway Granite.
Atlantic.
Franconia Breccia Group.
Montalban.
Lake Gneiss.
Bethlehem.
Laurentian.
Porphyritic Gneiss.

WALLING'S ATLAS OF NEW HAMPSHIRE,
1877.

Palæozoic,
Silurian.
Slates, Conglomerates, etc.
Helderberg Limestones.
Cambrian.
Mt. Mote Conglomerate.
Clay Slates.
Coös Group.
Calciferous Mica Schists.
Rockingham Schists.
Huronian.
Auriferous Conglomerate.
Lyman Group.
Lisbon Group.
Labrador or Pemigewasset.
Exeter Syenites.
Compact Feldspar.
Ossipyte.
Chocorua Granite.
Albany Granite.
Conway Granite.
Atlantic.
Franconia Breccia.
Montalban or White Mountain Series.
Lake Winnipiseogee Gneiss.

Bethlehem Gneiss.
Laurentian.
Porphyritic Gneiss.

GEOLOGY OF NEW HAMPSHIRE, 1877.
ii, 674, 675.

I. Stratified Groups.

Palæozoic.
Lower Helderberg.
Calciferous Mica Schist.
Coös Group.
Staurolite Slate.
Mica Schist.
Quartzyte.
Cambrian Slates.
Palæozoic (?).
Kearsarge Audalusite Group.
Rockingham Mica Schist.
Merrimac Group.
Ferruginous Slates.
Eozoic.
Upper Huronian.
Auriferous Conglomerate.
Lyman Group.
Lisbon Group.
Swift Water Series.
Hornblende Schist.
Lower Huronian.
Labrador.
Montalban.
Franconia Breccia.
Fibrolite Schists.
Ferruginous Schists.
Concord Granite.
Gneiss and Feldspathic Mica Schists.
Laurentian.
Lake Winnipiseogee Gneiss.
Bethlehem Fine-grained Gneiss.
Bethlehem Ordinary Gneiss.
Porphyritic Gneiss.

II. Eruptive Masses.

Augitic.
Diabase.
Diorite.
Feldspathic.
Trachyte.
Pequawket Breccia.
Porphyry.
Labradorite Diorite.
Granitic.
Exeter Syenite and Diorite.
Syenite of Mt. Gunstock, &c.
Granite not otherwise Assigned.
Granite cutting Coös Group.
Chocorua Series.
Albany Granite.
Conway Granite.

In a region where palæontological aids to investigation are wanting, the geologist must rely on indications of superposition, physical conformities, characteristic minerals and petrographic resemblances. The application of the petrographic criterion is involved in distracting difficulties by the progressive and unequally-paced changes which crystalline aggregations have undergone in the presence of the dynamic agents of geology. Hence the greater necessity for seeking always the evidences from superposition. Professor Hitchcock, with a true evaluation of the only expedients available, enunciated in 1873, the fundamental principles by which he was guided:

"Logan, in 1855," he says, "described a system of rocks overlying unconformably the Laurentian gneisses about Lake Huron, which were distinguished by means of lithological characters. All geologists, therefore, who use the name Huronian, of necessity practically adopt this principle, though perhaps insensibly. We do not claim that a talcose rock can never be found in any other system than the Huronian, nor that gneiss may never be stratified with the hydromicas. Professor Dana's recent paper shows that gneisses, quartzites and limestones are interstratified in the Silurian of western New England.* In no instance would we claim that mineral character is sufficient to distinguish systems without

Proc. Amer. Assoc., 1873, Sec. B, p. 147.

a study of the relations of the strata. We may sometimes generalize, and believe that rocks of similar mineral characters must be of the same age, but such speculations must always provide for confirmation by a study of the strata."*

An application of the mineralogical criterion is seen in what, in the report for 1870, is called "porphyritic gneiss."

"There are over Thirty areas of porphyritic gneiss in which the feldspar crystals are very conspicuous for their size, the rock being the *Augen-gneiss* of Europe. I assume that all the areas of this rock are identical in age, and in speculating upon the relative positions of the intervening groups, rely upon the correctness of this starting-point.** The fact of minor differences would seem to confirm our assumption of their identity in age, just as the palæontologist finds, from the presence of the same fossils, proof of contemporaneity in the rocks with dissimilar mineral character. From these facts it is inferred that the porphyritic gneiss is older than the Lake or the Montalban gneisses, the last being the newest.** It may as well be said now as at any time, that nothing older than the porphyritic gneiss has yet been discovered. This formation constituted the first dry land in the State."†

Professor Hitchcock's changes of opinion are illustrated in his record in reference to the Norian. This division, following Hunt, was first introduced into the report for 1871. Of its relative position he says:

"All will agree that the mineral labradorite belongs to the original Laurentian system; and therefore, by its discovery in New Hampshire, will be satisfied that some of our crystalline rocks belong to the older series of the Eozoic, and not the Palæozoic. Hence the prevalent opinion respecting the age of the New England metamorphic rocks must be changed to conform with the discovery of labradorite in our state.* * Our conclusions as to the absolute and relative ages of the New Hampshire formations depend upon the reference of some of them to the Norian system of Hunt."‡

Professor Hitchcock, therefore, in establishing the high geolog-

*Pro. Amer. Assoc., 1873, Sec. B. p. 147.

†*Final Report* vol. ii, pp. 659, 660, 663, 664.

‡*Report, 1871*, pp. 4-10. The allusion made in the above paragraph may be illustrated by the following citations: "To the Chemung and Portage group of New York* * may perhaps be referred, in part, the rocks of the White Mountains (Hunt, *Amer. Jour. Sci.* 1850, II. ix, p. 19; *Proc. Amer. Assoc.* 1849, II, pp. 333,334.) "It is moreover probable that the rocks of New Hampshire, including the White Mountains, are altered strata of Devonian age." (Hunt, *Geol. of Canada*, 1863, p. 598.) The same opinion was reiterated in 1867 (*Esquisse géologique du Canada*, p. 23; *Bull. Soc. géologique de France*, 1867, II, xxiv. p. 687.) In 1860, professor J. P. Lesley expressed the opinion that the range of the White Mountains would prove to be synclinal instead of anticlinal, and therefore of probable Devonian age. (*Proc. Acad. Nat. Sci. Phil.*, 1860, xii, pp. 363-364.) Logan, also, accord-

ical antiquity of the White mountains, had a long-strengthening sentiment to combat. It was recognized however as Norian by Hunt, in 1873.*

In 1872, Hitchcock more formally defended the supposed sedimentary character of these rocks:

"It is a perplexing matter to determine the lines of stratification, as the outcrops are divided by two prominent sets of jointed planes, either of which might be called layers of deposition, the rock being essentially homogeneous. One set dip 20° northerly, and are the most numerous, The other dip about 75° W10°S."†

In the Report for 1872, published later than this, he adds:

"As the latter [joints] correspond better in position with the supposed strata of nodular gneiss, it was thought they indicated the proper lines of deposition."‡

These beliefs were iterated in 1872. Referring to the same locality and the same terrane, he says:

"The rock seems to be stratified, its planes dipping about 20° northerly * * The importance of this discovery may be best appreciated by remembering that the presence of the lime feldspars affords a strong presumption that the rocks are Eozoic, and not metamorphic Palæozoic formations. It seems to be generally admitted by geologists that the feldspars are confined to the older rocks, except as found in eruptive trappean and volcanic masses."§

In the second volume of the Final Report, he adheres to the same opinions:

"I was at first satisfied that this rock was gneiss, but did not recognize its true place in the porphyritic group. Subsequently I referred it to the "trachytic" or Albany granite, but a re-examination in 1875, shows that it belongs to the oldest of our formations, and is distinctly stratified, traversed by trap dykes, and narrow banded veins of quartz * * The labradorite rocks with a very moderate dip, rest unconformably upon the greatly upturned edges of the Montalban schists, as if there had been large upheavals at the close of the Montalban period, and comparatively little disturbance since. * * The facts as interpreted, are of great consequence, since they fix the geological horizon of the whole

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ing to Hunt, regarded them as probably "altered Devonian strata" (*Azoic Rocks* pp. 86, 87, 182.) (See also *Amer. Jour. Sci.*, II, ix, 19, 1849; II, xxxi. 403, 1861.) In 1870, Hunt pronounced the White mountains Terranovan. *Amer. Jour. Sci.*, II. l. 83-90, 1870. The various older opinions are reviewed at length by Hitchcock in Final Report, ii, 184, 198, 264-7.

**Proc. Boston Soc. Nat. Hist.* xv, p. 310, 1873.

†"The Norian Rocks of New Hampshire," *Amer. Jour. Sci.* III, iii, 43-47, 1872.

‡*Ann. Rep. 1872.*, pp. 15, 16.

§*Proc. Amer. Assoc.*, *1872.*, xxi, pp. 135-151.

Atlantic system, while considerations of a stratigraphical character confirm this impression. * * The discovery of the Labrador system, overlying the most abundant and characteristic White Mountain strata, makes it clear that the latter are older than the former, which are confessedly Eozoic."*

In spite of this oft repeated conviction of the sedimentary nature of these labradorite rocks, and of their occurrence in seven different areas among the White mountains, we find professor Hitchcock on a later page of the same volume, employing the following language:

"The Labrador system, if present in New Hampshire, is in very limited amount. Recent investigations make it difficult to say that the labradorite rocks are not of eruptive character. They have the composition of dolerite; and certain exposures of them upon Mount Washington are surely injected dykes. Hence great doubt arises whether the larger area of Waterville really represents the Labrador system of Canada. At all events, its age is great, for these dykes cut through the Montalban strata [He had very recently said the labradorite rocks rest discordantly on the upturned edges of the Montalban]. This dolerite may be regarded as one of the oldest eruptive rocks in the State, coming to the surface in what was the labrador age of the world."†

The eruptive nature of this mass was detected by Dr. Hawes; and is recorded in the third volume of the New Hampshire report, dated 1878, though it does not appear at what date Part iii was printed, nor at what earlier date it was prepared. He says:

"Gabbro is found in immense masses in Waterville and in the vicinity of Mount Washington. The relationships of its masses to the surrounding strata are not so easily determined as those of the little dikes of diabase and diorite, the walls of which are usually plainly seen; but at some points the rock possesses all the structure of an eruptive mass and when, in other places, this is not found, the evidence furnished by more favorable localities, as well as that furnished by allied rocks in other lands where they have been more thoroughly investigated, must at present be decisive."‡

Dr. Hunt now found occasion to change his position:

"The labradorite rocks in the White Mountains, which had by Hitchcock been referred to norite, are now found by him to be eruptive masses."§

The "porphyritic gneiss" always commanded the attention of

*_Final Report_ II. pp. 214,258,266.
*_Final Report_, ii, p. 667.
‡_Final Report New Hampshire_. iii, p. 165.
§_Azoic Rocks_, p. 151.

professor Hitchcock. He early published observations as follows:

"The sections given of the common granite, trachytic granite and the Norian series (or at least certain felsites) seem to determine their relative positions, the last being at the top. The brecciated granites of Franconia seem to be older than any of these and to underlie them. * * If these points are assumed, the porphyritic gneiss can be shown to be at the bottom of the series, for it lies outside of the lowest of them."*

In the next annual report the "porphyritic group is described as consisting "mainly of gneiss full of large crystals of orthoclase feldspar, associated with ferruginous and other bands. It is regarded as the oldest of all the formations in the State," for reasons which are enumerated."†

The position of this gneiss is again referred to:

"If the felsite series is of the age of the Upper Laurentian or Labrador of Logan, then by the law of superposition, the strata underneath the common granite are Lower Laurentian. Observation showed us, at this phase in the development of the White Mountain structure, two gneisses and a breccia underneath the granitic sheet. The most important is the "Porphyritic gneiss," or granite sometimes. This is a gneiss having large crystals, usually one and a half inches long, of orthoclase, arranged in layers in the mass, with the longer axes parallel to each other. These we conceive to be the strata.* *

"The descriptions of the Laurentian rocks in Canada and Europe make mention of large quantities of porphyritic gneiss ; hence we feel warranted in referring these lower schists to the Laurentian system. We have found nothing older in the state." ‡

Again, in a later discussion of the parallelism of the groups recognized in New Hampshire, having mentioned the Canadian systems, Laurentian, Labrador, Huronian and Cambrian, he says :

"The first two of our groups may be referred to the oldest of these, the Laurentian, without hesitation. We do not possess exhaustive information about the occurrence of this oldest system in other regions. So far as is understood, there are two sorts of associated rocks in its typical localities, one being largely pyroxenic. That variety is wanting in New Hampshire. A porphyritic or *Augen-gneiss* is eminently characteristic of the fundamental rocks in every part of the world; and hence ours may readily be called Laurentian. * * [After correlating succeeding New Hampshire

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**Annual Report*, 1871, pp. 25-27.

†*Annual Report*, 1872, p 11.

‡*Proc. Amer. Assoc.*, 1872, xxi, pp. 145-6.

groups, he continues.] The Montalban series are certainly not characteristic of the Laurentian. * * Dr. Hunt is satisfied that they overlie the Huronian or greenstones. Our own observations lead to the view that the typical Montalban rocks underlie the same, as recently stated, though the precise relationship is not beyond controversy." *

I make but two citations further bearing on the structural character and taxonomic disposition of New Hampshire Archæan rocks. The first is connected with the genesis of certain systems :

"If these granites behave like a stratified formation, of course the question is at once raised whether they should not be regarded as true strata. The answer cannot be given from position merely, since it is not uncommon to find sheets of trap or lava holding a perfectly analogous position. We have preferred to think of the White Mountain country, at the end of the Laurentian period, as an immense basin, upon which there was an overflow of common granite. Being liquid it spread itself out like water, assuming a horizontal surface. After a while, there was an eruption of trachytic granite, which spread itself in the same way. Subsequently the felsites were formed above them conformably. It would be natural to regard these granites and felsites as belonging to one period, the Norian. The limits of this system have not been fixed; and it seems as if in New Hampshire, it should commence in the common granite and end with the red orthoclase felsite."†

The second citation is an observation of Mr. Huntington, who says of the porphyritic gneiss :

"The fact that rounded fragments of a dark gneiss are found in the porphyritic, shows that the porphyritic rock in Fitzwilliam is either intrusive, or that in the process of metamorphism, these fragments were not obliterated, and that the dark gneiss — which is very limited, but resembles some varieties of the Bethlehem gneiss — is the older rock." ‡

Reference has been made to the evidence borne on the pages of the Vermont and New Hampshire reports, that the geological disorder reigning in those states is of the most perplexing character. Observations of strike and dip defy co-ordination, except within very limited areas. Many pages are devoted, in different portions of the second volume, to records of dip and strike, but no general tendencies to groups or systems of strikes is distinctly apparent.

Final Report, ii, 668, 669. See further, pp. 98, 99, 102, 274.

**Proc. Amer. Assoc.*, 1872, xxi, 145.

**Final Report*, ii, 472. See also, pp. 513-514.

I copy at random, for illustration, the records made of the dip of the rocks of the "Montalban series" in a single town, Grafton :

At McKelton's, S. 60° E., 72°.
At mica quarry, N. 32° E., 80°.
At west side, S. 50° E., 75°.
At north, S. 63° E., 70°.
At ¼ mile southeast of J. Martin's, S. 78° E., 70°.
At Alger hill, N. 62° E., 75°.
At H. Bullock's, S. 38° E., 50°.
At Prescott hill, N. 82° E., 40°.
¼ mile northeast of T. Foss', S. 65° E., 70.°
At Mrs. Arvin's, S. 62° E., 78.°
At Tewkesbury pond, S. 33° E., 75.°

Nevertheless, professor Hithchcock has given us, near the close of this volume, a chart of "Principal axial Lines of Vermont and New Hampshire." He says: "This is the final summing up of all the multitudinous observations of this report. * * This map and the statements of the last few pages are the key to Part II. They are the generalizations derived from our entire work, both in the New Hampshire and Vermont surveys."*

Turning to the chart, we observe a series of broadly sinuous lines drawn across the two states, having in western Vermont a general direction nearly north and south; in the eastern part of the state, a general conformity to the trend of the Connecticut river; and in New Hampshire, a still stronger tendency to a NNE direction, with some irregularities in the White Mountain region. These are simply lines of observed structure. We are told also, that at every point, they are the average of the different strikes observed. This is worth something; but geologists will be better satisfied, when, from this multitude of discrete data, some later hand, if not professor Hitchcock's, shall have evolved the deep historic and genetic truth concerning the sequence and vicissitudes of this puzzling complex of terranes.

THOMAS BENTON BROOKS.

1873. The progress of the investigation undertaken by Major Brooks under the auspices of the Geological Survey of Michigan, in 1869, was shaped by complete sympathy with the general views then prevailing; and those, it is just to say, were strictly Canadian. The Canadian survey had settled in the conviction that the iron-bearing rocks of the Marquette region were all of one age, and they were of the same age as the rocks north of lake Huron which they

**Final Report*, II, p. 673.

had long known as Huronian. Thus the geologists of Michigan came into the traditional belief that the whole territory of the Northern Peninsula of the state was covered by the Huronian and Laurentian systems—save the recognized Lower Silurian angle at the east—the St. Mary's peninsula. Major Brooks, as the result of four years of investigation, concluded that the whole geology of the Marquette district above the Laurentian, might be embraced in a certain number of groups, which he designated numerically. As the characterization of these groups will be the best exhibit of major Brooks' views, and as these numerical designations are necessary matters of frequent reference among geologists, they will be at once presented.*

XX. *Granites* southwest of Lake Michigamme (Taken from *Wis. Rep.*, iii. 648.

XIX. Grayish-black *Mica-Schist*, often staurolitic, and holding andalusite and garnets, Rarely *chloritic schists.*

XVIII. (Doubtful). *Quartzyte* west end of Lake Michigamme?

XVII. *Anthophyllitic schist*, with iron and manganese.

XVI. (Uncertain.) Contains some hæmatite.

XV. *Argillyte.*

XIV. *Quartzyte*, often conglomeritic. Position immediately over the ore. Contains neither marble, talc nor novaculyte; very rarely argillyte.

XIII. *Specular and magnetic ore.* The principal bed.

XII. Banded, ferruginous, *Jaspery schist.*

XI. Coarse *dioryte*, with a light grayish and reddish feldspar.

X. *Silicious, ferruginous schists.*

IX. *Dioritic rock.*

VIII. Silicious, *magnetic schists.* "Flag-ores."

VII. *Dioritic rock.*

VI. Silicious, magnetic, banded, *chloritic schists.*

V. *Quartzyte*, sometimes containing marble (used as flux) and beds of *argillyte* and *novaculyte.* Very persistent. Very seldom conglomeritic.

IV. *Silicious, ferruginious schist.*

III. *Silicious, ferruginious schist.*

II. *Silicious, ferruginous schist.*

I. *Silicious, ferruginous schist.*

[The crystalline schists follow below.]

"These beds," he says, "appear to be metamorphosed sedimentary strata, having many folds or corrugations, thereby forming in

*The table is compiled from the *Michigan Report*, Vol. i, pp. 85-116.

the Marquette region, an irregular trough or basin, which, commencing on the shore of Lake Superior, extends west more than forty miles * * While some of the beds present lithological characters so constant that they can be identified wherever seen; others undergo great changes. Marble passes into quartzite, which in turn, graduates into novaculite; diorites almost porphyritic, are the equivalents of soft magnesian schists. * * The total thickness of the whole series in the Marquette region, * * may aggregate 5,000 feet.

"Near the junction of the Huronian and Laurentian systems, in the Marquette region, are several varieties of gneissic rocks, composed in the main of crystalline feldspar, with glassy quartz and much chlorite. Intersecting these are beds of hornblendic schist, argillite and sometimes chloritic schist. These rocks are entirely beneath all the iron beds, seem to contain no useful minerals or ores, and are of uncertain age. No attempt is here made to describe or classify them." (p. 84.)

Of the "diorytes, dioritic schists and related rocks" he says: "These obscurely bedded rocks * * range in structure from very fine-grained or compact (almost aphanitic) to coarsely granular and crystalline, being sometimes porphyritic in character. * * On the one hand it graduates into a heavier, tougher, blacker variety, which is unquestionably hornblende-rock, with some feldspar. * * On the other hand, it passes into a softer, lighter colored rock, of lower specific gravity, which while it has the same streak, weathers similar to true diorite, is eminently schistose in character, splitting easily, and appearing more like chloritic schist than any other rock. (p.99.)

"At several points, dioritic schists, semi-amygdaloidal in character, were observed; and in one instance, the rock had a strong resemblance to a conglomerate." (p. 99.)

"At Republic mountain, a doleritic schist graduates into a black mica-schist," (p. 100). Dr. Hunt expresses the opinion that in the case of Marquette diorites the hornblendic mineral often becomes softened and hydrated, passing into a degenerate form more nearly allied to chlorite or delessite (in which water is an essential constituent) than to a true hornblende." (p. 101.)

"The bedding of the rocks is generally obscure, and in the granular varieties, entirely wanting. It is usually only after a full study of the rock in mass, and after its relations with the under- and overlying beds are fully made out, that one becomes convinced, whatever its origin, it presents in mass, precisely the same phenomena, as regards stratification, as do the accompanying schists and quartzites." (p. 102.)

Of magnesian schists, ("mostly chloritic,") he says:

"Intercalated with the pure and hard mixed ores at all the mines worked in formation XIII, are layers of a soft, schistose rock, of some shade of grayish-green, and often talcy in feeling. * * It is unquestionably a magnesian schist, varying from chloritic to talcose in character, and sometimes apparently containing a large percentage of argillite." (p. 104.)

"A very peculiar occurrence of this rock are the so-called 'slate-dykes,' which can be seen at the New England, Lake Superior and Jackson mines, but still better in the quartzite ridge just north of the outlet of Teal Lake."*

Speaking of the quartzyte (No. XIV,) he says:

"As if to leave in our minds no shadow of doubt as to the sedimentary origin of this rock, nature has, in addition to the conglomerate on the Spurr mountain range, given us a variety of the Upper Quartzite, which can only be described as a fine grained, friable banded sandstone." (p. 108.)

In discussing argillytes, he says, in addition to beds interstratified in the quartzytes:

"At least two distinct beds of argillite have been made out; one immediately beneath the ferruginous schist of formation X, to be seen in outcrop on the south shore of Teal Lake, near west end, and in the rail-road cut about one mile east of Negaunee. Another and far more extensive bed is XV, which forms the stratum next above the upper quartzite. Color usually dark brown or blackish; but where associated with the marble, it is sometimes reddish. It has a true slaty cleavage distinct from the bedding. * * Black, carbonaceous matter is often present." (p. 111.)

"Beyond the limits of the Marquette region, we find in the recently explored Huron Bay District, the finest clay-slates so far discovered in Michigan."† Within the Marquette district, he finds a carbonaceous shale more highly charged with graphitic material, "of a bluish-black color, but burns white before the blow-pipe, marks paper like a piece of charcoal, is soft and brittle, slaty in structure, and having a specific gravity of but 2.06."

"This rock has been found in the Marquette region only at two localities: 1. The S. C. Smith mine, T 45, R 25, where it seems to bound the iron ore formation on the northeast. 2. On the south side of Sec. 9, T. 49, R. 33, along Plumbago brook." Analy-

*_See_ this occurrence described by the writer in _XVI Ann. Rep. Minn._ p. 180.

†This shale is recognized as identical with that occurring west of lake Gogebic.

sis gave professor Brush 20.86 percent carbon. "The analyses prove the material to have no commercial value, but possesses scientific interest as proving the existence of a large amount of carbon in the Huronian rocks. The equivalency of these shales with the members of the Marquette series has not been established; they are undoubtedly Huronian, and are, I suppose, younger than the ore formation XIII." (116.)

Major Brooks reported also, in a condensed way, on the Menominee Iron Range (pp. 157-182,) and very briefly, on the Lake Gogebic and Montreal river Iron Range (pp. 183-6). In connection with the latter, he presents a section showing the unconformable junction of the (so-called) Huronian with the (so-called) Laurentian. This is the same unconformity as has since been pointed out by Sweet, Irving and others.*

1879. Major Brooks, in 1879, made further publication of his views respecting the Menominee region, and particularly, that part of it which extends into Wisconsin.† Of his earlier Michigan work he makes the following memorandum:

"My reconnoissance of the northeastern side of the Menominee, the results of which are given in the Geological Survey of Michigan, vol. I, 1873, gave valuable data; but that work on the whole, was incomplete and crude, and will be superceded by this report, which is, however, not complete in several directions."‡

He recognizes the "Keweenaw (copper series)" among the rocks of his district. The Huronian, he states, is "known to rest nonconformably on the granite and gneissic rocks, regarded as of Laurentian age." [He is here understood to refer to the Penokee unconformity.] As to the Huronian, he claims to have succeeded in determining, in the Menominee region, the equivalents of his numbered groups in the Marquette region; and it will be useful to reproduce the essential parts of his table:

XX. *Granite, gneiss* and *porphyryte.*

XIX. *Mica-schist, hornblende-schist* and *gneiss.* Black, subcarbonaceous *slate* and *chloritic schists.*

XVIII. (Not observed.)

Trans. Wis. Acad., 1875-6, III, 43-44; *Amer. Jour. Sci.*, 1877, III, xiii, 308. This Whitney and Wadsworth call a "supposed unconformability" (*Bull. Mus. Comp. Zoöl.*, vii, 495, 496, 497), adding that "the proof advanced was, that the foliation of the granite and gneiss dipped at a different angle from that of the Huronian rocks." * * "They have failed to observe the phenomena of contact, when seen, beyond the mere fact of a different dip to the foliation observed." Such too frequent rude contradictions might with more courtesy have given place to expressions of doubt; but, with more justice, to expressions of respect for the authority of such excellent observers.

†*Geology of Wisconsin*, vol. III, Pt. vii, pp. 429-459, with appended microscopical observations by Dr. Arthur Wichmann (of Leipzig), pp. 600-656, and Appendices, pp. 657-663.

‡*Geology of Wisconsin*, iii, p. 431.

XVII. Gray *gneiss* with small crystals of triclinic feldspar, and large ones of orthoclase. Associated with hornblende-chloritic-and micaceous-*quartz-schist*. The Commonwealth Iron horizon.

XVI. Schistose *greenstone*, with micaceous, chloritic, quartzose varieties. *Dioryte* (gabbro?).

XV. (Not identified.)

XIV. Light-gray, specular, conglomeritic *quartz-schist*, containing mica and magnetite.

XIII-VIII. (Not identified.)

VII. Gray and red, soft, unctous, *hydromicaceous schist*, graduating into *clay-slate*.

VI. *Iron ore*. Banded, quartzose, ferruginious *schist*.

V. *Dolomite marble* with cherty laminæ. Very thick and prominent.

IV and III. (Not identified.)

II. Lower *quartzyte*, massive to semi-schistose, arenaceous, in places micaceous and actinolitic, with occasional specular ore. Felch mountain supposed in this horizon.

I. Chloritic *gneiss*; hydrous-magnesian *schist*; *slate-conglomerate*; *quartzyte* and perhaps *dioryte*. (Possibly Laurentian.)

Comparing the Huronian rocks of different regions, Major Brooks reaches the following conclusions:

1. The Huronian rocks are generally rich in species and varieties, but the maximum of varieties is found in the Marquette and Menominee regions."

2. "The points of resemblance between the Marquette, Menominee, Sunday Lake and Penokee series are so numerous as to point, I think, unmistakably to their having been formed in one basin, and under essentially like conditions."

He adds:

"Those who are not disposed to admit that lithology affords much assistance in identifying rock-beds over even small areas, should have in mind that the Lower Silurian sandstone can now be seen quite uniform in character, over a much greater area in the same region. Almost the same remark may be made of the underlying Keweenian rocks. Cannot approximately as favorable conditions have existed for the formation of a particular kind of rock over a smaller area at the earlier period?"*

**Geology of Wisconsin*, iii, 449-50.

Newton Horace Winchell.

1873. The second season of the Geological survey of Minnesota found professor Winchell engaged in an examination of the geology of the Minnesota river. In describing the outcrops of the "Granites of the Valley," * he noted some features which, in his later researches have proved to possess great significance, the older observers either not having noticed them, or failed to inquire under what conditions they have been produced. This granite is the common ternary variety. In the neighborhood of Granite Falls, he says, in his description, "there are sudden changes in the rock, from real granite to hornblende schist. These occur irregularly." He speaks of the formation as having a dip, and supposes it due to original sedimentation.

1880. The ninth annual report† of the Geological survey of Minnesota contains "A Preliminary List of Rocks," 442 in number, collected by professor Winchell, on a tour made during the season of 1878, from Duluth along the north shore of lake Superior, to Pigeon point, and thence through the interior by the line of lakes and streams marking the international boundary, westward to Vermilion lake, and still thence to the Mississippi river. Both portions of the route had been previously traversed—the line from Grand Portage along the boundary, by Houghton, Norwood, the Canadian geologists, and a long succession of traders; but nc previous explorer had gone with so settled a purpose to penetrate the mysteries of the off-shore geology; and no one had made its study the chief end of his visit. Norwood was on a hasty reconnoissance over an extended line; Houghton made a brief excursion as far as to Mountain lake and returned; and Bell passed over the route chiefly for the purpose of reaching the Canadian territories about the Lake of the Woods. The tour of 1878 was somewhat carefully studied, step by step. Not only were rock masses investigated petrographically and structurally, but the plans of the contours of the country, the systems of their building up, the great obvious movements by which juxtapositions and superpositions had been effected—these fundamental phenomena were all taken in by a broad sweep of observation, and the problems connected with them, if not at the time resolved, were placed in the midst of surroundings which continued thereafter to throw important light on them. It is worth the while to note some of the observations made—at the time, apparently isolated, but afterward wrought

**Second Annual Report of Minnesota*, 1873, pp. 160-176.
†*Ninth Report*, pp. 10-114.

into the great geological conceptions which seem now to represent much of the truth.

On the west side of Grand Portage, slate was seen which was probably the first recognition in Minnesota of the Animike formaion, isolated by Hunt in 1873, and of which so much was to become known. This is subsequently identified as the "silico-argillaceous slate" of Norwood. The "slate and quartzyte of Pigeon River Falls" are said to dip south. Numerous islands off the shore are visited. The principal rock-axis of Pigeon point peninsula, is, he says, "not evidently a dyke, but a massively bedded or coarsely jointed formation which extends west, and soon rises over fifty feet from the water, and shows a basaltic, mountain-like structure. It resembles the rock and structure of Rice point (near Duluth) and may be parallelized with it in age, and here is associated, as there, with a red, metamorphosed rock. Here, however, it is a part of the Animikie beds of Dr. T. Sterry Hunt, which would therefore seem to be only a downward extension of the Cupriferous series."

Proceeding as far as Mountain lake, he remarks "that these hills are all short monoclinals of gray quartzyte, with beds of argillaceous and black slate, dipping uniformly in a southerly direction, and covered with a greater or less thickness of the trap rock (gabbro?) of the country—the trap being sometimes one hundred feet thick, but generally less than fifty feet, and often the only rock seen, the lower beds being hid by the copious *talus*. The slate in some places has a dip slightly southwest, and the inclination amounts, usually, to about 8 or 10 degrees. The trap also dips with the slate, so that the hills have gradual slopes toward the south and steep slopes toward the north, or are perpendicular—indeed, they most frequently are perpendicular for about twenty-five feet from the top, or even one hundred feet, the trap having a widely basaltic structure, which causes it to fall away in perpendicular columns; the slate and quartzyte also, have frequent perpendicular jointage planes, which also facilitate the perpendicular breaking of the beds. The quartzyte is evenly and conspicuously bedded† without any confusion, but alternates, both gradually and suddenly with the black argillaceous slate. The most of it as far as seen to this place, is gray quartzyte. This quartzyte must be an immense formation, as it is that seen at Grand Portage, and all over Pigeon point, and the islands off the point."

**Ninth Report*, pp 69-70.

†The beds called here "quartzyte" are what the writer, in speaking of these formations, has styled interbeddings of "silicious (often jaspery) schist."

"Several important questions pertaining to the geognosy of this formation arise in an attempt to describe it, which must, for the present, remain unanswered, but which, perhaps, future examinations may solve :

1st. Is this trap older than the uplift of the hills, or did it come over the country when the uplift occurred?

2d. Are the dykes that are seen crossing this trap (as at the foot of South Fowl lake) of the same age as the trap, or are they subsequent to it?

3d. How much of the topography here is due to glaciation?

4th. Do the monoclinal hills run under each other, or are they each separate and isolated uplifts?

5th. Can these beds of supposed igneous rock be due to a change in the sedimentary rocks, instead of igneous outflow?

6th. Why is there an entire absence of amygdaloids?"

Arriving at the north side of Gunflint lake, he notes "hydromica (?) slate." "This rock rises in knolls and hills one above the other, irregularly disposed. The slates stand nearly vertical, running E. 20° N. This passes insensibly into the next," and "graduates back and forth." This resembles some forms of the slate at Thompson on the St. Louis river (p. 82). Belonging to the same formation is a "greenish, porphyritic rock (with albite ?), having an imperfect, schistose and fibrous structure, and some free quartz, embraced much like veins, in the slate. It is not vein matter, but gradually changes to the slate, right and left, the slates standing nearly vertical.

"This outcrop is supposed to belong to what the Canadian geologists have styled the Huronian. It underlies the quartzyte and Gunflint beds [now known as Animike slates] apparently unconformably. At least, it is another and distinct formation from the slates at Grand Portage" (p. 82).

It is to be regretted that this clew was not followed up. This is the discordance which has become celebrated.*

Coming to the characteristic black, silico-argillitic slate which gives name to Knife lake, he styles this rock "a light green, tough magnesian rock [which] can perhaps be designated a chloritic or serpentinous quartzyte," and recognizes it as belonging to the (then called) Huronian slate series; and thus, fourteen years ago, excluding it from the crystalline schist series, to which, later, it has been referred.

1881. A similar journey was made in 1879, and the results are

*Compare also, p. 102 at bottom, and notice the curious speculation, p. 103. It is evident from this that it remains to discover flint and jasper beds in the Kewatin.

found in the report for 1881.* The studies attending this trip were pursued under circumstances promising still larger results. The Knife-lake slates and the schists, now known as Kewatin, were identified near the west end of lake Superior. The tour extended to Grand Marais and Silver Islet, and from Grand Marais to Ogishke Muncie and the mouth of Poplar river. On Mayhew and Loon lakes he examined again, the "great quartzyte and slate formation, or the Animikie group." He describes again, and in more detail, the remarkably flinty breccia on the north side of Gunflint lake, and speculates on the cause of its condition.† I quote the following obscure paragraph:

"The close proximity of this flint and jasper locality to the next great underlying formation (syenites and slates)‡ makes it one of great interest to the geologist, but so far as scrutinized as yet, the true relations of the two formations are not revealed by anything here seen, though there seems to be an unconformability between them." (p. 88.) I have elsewhere quoted this passage as intimating an unconformity between the "slate and quartzyte" and the vertical schists north but further east, on Gunflint lake. But I am not sure this is the author's meaning, because he seems to be comparing the brecciated formation with the (underlying?) slates.

Coming to Ogishke Muncie lake, he subjects the mysterious conglomerate to further investigation. Notwithstanding the length of the passage, it may be well to quote largely, so that the reader may compare the statements with those of Sir William Logan in speaking of the slate conglomerate of Thunder bay (See p. 132.) He says:

"The conglomeritic character is hardly distinguishable on a fresh fracture of the rock, which sometimes shows different shades of green. But all over the surface, when glaciated and weathered, are visible the forms of rounded bowlders included in the rock, the different forms, colors and grain of the bowlders being brought out plainly. This is essentially the same formation as the rock 743 and 737, and it constitutes by far the greatest part of the country rock about Ogishke Muncie lake. Wherein the rock 737 differs from 738, which also passes into 744 by the accession of slaty structure, and the obliteration or modification of it by the accession of bowlders, it may be ascribed to varying proximity to, and influence of, the underlying 'talcose' rocks, in the process of deposition and metamorphism. * * On the island [Campers',]

*_Tenth Annual Report Minnesota_, pp. 9-122.

†_Tenth Annual Report Minn._, p. 87.

‡The breccia locality is _within_ the slates of the "Quartzyte and Slate" formation.

it is a real conglomerate, with a smoothly glaciated surface, and the sections of some of the rounded stones are a foot, and even more, in diameter. They are very abundant. Sometimes the rounded stones make three quarters of the whole rock, but in other cases, the slaty matrix is nearly free from them, over considerable areas."

The author suggests the following order of superposition of the rocks in this part of Minnesota:

"1. The nearly horizontal quartzyte and slate formation composing the hills around the Grand Portage and the international boundary as far as Gunflint lake.

"2. The coarse grit or fine conglomerate, No. 738.

"3. The jaspery and calcareous beds that are known as the "Gunflint beds," Nos. 737, 743.

"4. The gray marble, No. 746. [See this further discussed in *XVIth Rep.* pp. 95–6.]

"5. The tilted slaty conglomerate, and the great conglomerate about Ogishke Muncie lake. Nos. 744, 750, 754.

"6. The amphibolyte and the chloritic slates, Nos. 731, 753, 348, 349, 350, 355, 356 and 358.

"7. Mica schists and alternations of mica schists and syenite. Nos. 335, 337, 339, 401, 406, 408, 414, 417.

"8. The syenites and granites of Saganaga and Gull lakes.*

"There is yet," he says, "one very important undetermined question relating to this generalized section, which ought to be borne in mind, viz: Is the great quartzyte and slate formation of the international boundary (No. 1 of this section) the same as the highly tilted slaty and quartzyte formation which passes into the great conglomerate (No. 5)? There are some considerations which seem to imply that it is, though in all descriptions and sections they have been treated as different terranes. (*a*) Where

*I venture to make, on these assignments, the following suggestions:

1. This clearly is the Animike.
2. This, I judge, is only a border condition of the Ogishke Conglomerate (See XVI *Ann. Rep. Minn*, pp. 313, 315). There are also, on the borders of Frog-rock and Townline lakes, several occurrences of gravelly sericitic schist—as also on Ensign lake. (XVI *Rep.* p. 312, Rock 863; and p. 315, Rock 889, 890.)
3. I feel constrained to regard these as no distinct part of the Animike. (See XVI *Rep.* p. 251.)
4. This is what is described as a bed of dolomyte in XVI *Rep.* p. 316.
5. The Ogishke Conglomerate.
6. By this I understand the author to mean the later-called "Kawasachong rock"—green chloritic slates (even if originally erupted); the "greenstone" hills south and north of Ogishke Muncie, and the chloritic and amphibolitic conditions of the "Kewatin" seen in many places.

No separate place is assigned here to the vertical schists.

These suggestions in a very perplexing inquiry, may be very wide of the mark.

the horizontal slates approach the syenites at the east end of Gunflint lake, there is nothing to be seen of any beds representing the tilted slates. The syenites and their associated schists come on at once. (*b*) Where the tilted slates and conglomerates associated with them are traceable from the syenite upward to the gabbro, as south of Ogishke Muncie lake, there is nothing to be seen of any beds like the horizontal black slates of No. 1. (*c*) The "Gunflint beds" appear to belong to the horizontal slates of the international boundary at Gunflint lake, but their supposed equivalents* at Ogishke Muncie lake belong to schistose and tilted slates and conglomerates. (*d*) Although the horizontal slates and quartzytes of the international boundary strike west and southwest across the state, forming one of the most important topographical features of the northern part of the state, and can be followed for many miles as such, yet they are lost entirely in the region of the upper St. Louis, and the tilted slates are the only ones seen where that river cuts the rock at Knife Falls and below.† (*e*) The great gabbro belt which surmounts the horizontal slates along the international boundary, and prevails to the east and south of their line of strike, is seen to pass to the west of lake Superior, at Duluth, and to disappear from sight suddenly between Duluth and Fond du Lac, as if its continuance depended on the maintenance of the horizontal formation with which it is associated. (*f*) Where the Gunflint beds become jaspery hæmatite, as south and east of Vermilion lake,‡ the structure of the tilted slates passes into the iron ore as if of the same formation. (*g*) The formation which underlies the Cupriferous at Fond du Lac is the tilted slates, and that which underlies it at Grand Portage is the horizontal slates."

"A thorough examination of the hill-range between Gunflint and Ogishke Muncie lakes would probably reveal the facts as to any transition from the horizontal slates to the tilted slates."§

From some confusion noted in the stratification of the region south of Ogishke Muncie lake, the author seems almost ready to adopt the alternative afterward embraced by professor Irving.

In a paper embodying descriptions of fifty thin sections prepared from the rocks of the Cupriferous series of lake Superior professor Winchell pointed out distinctly the two-fold origin of crystalline

*It is not obvious that any such beds are there. But, in any event, if we distinguish the horizontal slates holding the "Gunflint beds" from the vertical slates holding the conglomerate, no difficulty will exist.

†From (*a*), (*b*) and (*d*), it is not to be inferred that two systems do *not* exist, but that they are not co-extensive. Their coëxistence is seen on the north shore of Gunflint lake

‡The very distinct hæmatite formation also contains jaspery beds.

§This journey was made in 1887. See *XVIth Rpeort*, pp. 79-89.

rocks. He showed by demonstrations accompanying the memoir,* that the crystallizations resulting from metamorphism sometimes imitate closely the character and composition of the rocks whose eruptive escape has been the cause of the metamorphism. On the north of lake Superior, the contact of the gabbro with the red sandstone has produced "all stages of metamorphic change — from red sedimentary shale and sandstone to red felsite and syenite." A sedimentary rock heated to the point of fusion of the feldspathic constituents, and then cooled, will exhibit a non-differentiated ground, with feldspar crystals porphyritically disseminated. Heated completely to the fusing point and then cooled, the least fusible mineral — probably quartz, would first crystallize out, and later crystallizations would be penetrated by the older quartz. Simultaneously, the intrusive matter would impart certain constituents to the softened sedimentary bed, and minerals would arise for which the requisite constituents had not before existed in the bed.†

1884. At the Philadelphia Meeting of the American Association, he delivered an address before the Section of Geology as its president in which he discussed "The Crystalline Rocks of the Northwest."‡ This was a broad survey in which he attempted to arrange the succession of the great Archæan terranes, and point out their relations according to the views of other geologists. As the table at the end contains a convenient synopsis of the positions taken that will be here first introduced.

**Proc. Amer. Assoc.*, 1881, XXX, 160-6. Also *Tenth Ann. Rep. Geol. Minn.*, pp. 137-143. The subject was earlier discussed in *Proc. Amer. Assoc.*, 1880, XXIX, pp. 422-425, Comp. also, Tenth Rep., pp. 108, 111.

†The phenomena here referred to are of the same character as those which professor Bailey has since described and explained. See *Amer. Jour. Sci.*, III, xxxix, 273-280, Apr. 1890.

‡*Proc. Amer. Assoc.*, 1885, Pt. II, pp. 363-379; *XIIIth Minn. Report*, pp. 124-130; *Amer. Naturalist*, xviii, 984-1,000, 1884; *Science*, iv, 239-240, Sep. 12, 1884 (abbreviated.)

GROUPS.	EMMONS.	HUNT.	BROOKS.	IRVING.	Equivalents in Michigan.	Equivalents in Wisconsin.	Equivalents in Minnesota.
GROUP I. Granite and Syenite with Gabbro.	Hypersthene Rock. (Regarded as part of the Primary.)	MONTALBAN. Labradorian. Norian Upper Laurentian. Aronian.	Youngest Huronian.	Base of the Keweenawan.	XX	I and Ia. at Black River.	Duluth. Brulé Mountain. Misquah Hills. Beaver Bay.
GROUP II. Mica Schist.			The Huronian of Brooks. 1873.	The Huronian of Irving. 1879.	XIX at Marquette. XVII—XIX at Menominee.	XX—XXII at Penokee.	Little Falls. Pike Rapids. Outlet of Vermilion Lake.
GROUP III. Carbonaceous and Arenaceous Black Slate.	TACONIC SYSTEM, 1842-1846. Black Slate.	Animike.			XIV—XVII at Marquette. XV and XVI at Menominee.	VI—XVI at Penokee.	Animike. Black Slates. Grand Portage.
GROUP IV. Hydromica and Magnesian Slate.	Taconic Slate.				VI—XIV at Marquette. VI—XI at Menominee.	IV—VI at Penokee.	At "The Mission" Vermilion Lake, Vermilion Iron Mines.
GROUP V. Quartzyte and Marble.	Stockbridge Marble. Granular Quartz Rock.	The Huronian of Canada, 1855.			V at Marquette. II—V at Menominee.	I—III at Penokee.	Ogishke Muncie Lake.
GROUP VI. Granite and Gneiss with Hornblendic Gneiss.	Primary.	Laurentian.	Laurentian.	Laurentian.	Laurentian.	Laurentian.	Laurentian.

The author of this table comments upon his "Groups," in substance, as follows:

FIRST GROUP. Is represented in Minnesota by the gabbro and red syenite at Duluth. * * The outcrop of red granite near New Ulm, lying under the conglomerate and red quartzyte, is probably in the southwestward line of extension of this group.

SECOND GROUP. Consists of schists that are micaceous and often staurolitic as well as garnetiferous. Variously associated with beds and veins of granite and gneiss. Has a maximum thickness of 5,000 feet.

THIRD GROUP. Sometimes passes into roofing slates, with beds of iron ore, quartzyte and dioryte. "Includes the black slates of the Animike group in northern Minnesota, of Knife lake, Knife Portage on the St. Louis river; and carbonaceous shales lately reported near Aitkin on the Mississippi river. Thickness, 2,600 feet.

FOURTH GROUP. Schists soft and obscure, becoming quartzose and also hæmatitic; also with numerous beds of dioryte. In Minnesota, this is the iron-bearing horizon at Vermilion lake. Maximum thickness, 4,450 feet.

FIFTH GROUP. Represented by No. V. at Marquette, Nos. II. and V. at Menominee, and Nos. I. and III. at Penokee. The marble lies above the quartzyte, and in the Menominee region has a minimum thickness of 1,000 feet; while at Marquette, it graduates into a dolomitic quartzyte of indefinite extent, the whole group being there essentially quartzyte. A most persistent and well-marked horizon. The quartzyte sometimes holds feldspar, thus having the appearance of granulyte. In Minnesota this horizon seems to run along the south side of Ogishke Muncie lake, near the international boundary, and includes perhaps the great slate conglomerate which is there represented. This seems to correspond to the lower portion of the great quartzyte of this group, and to be the equivalent of the "lower slate-conglomerate" of the typical Huronian in Canada. Normal thickness from 400 to 1,000 feet; but if the great conglomerate of Ogishke Muncie be included here, the thickness of this group in northern Minnesota will exceed 6,000 feet.

SIXTH GROUP. In Minnesota, found on the international boundary, at Saganaga lake, and large boulders from it are included in the overlying conglomerate at Ogishke Muncie lake, showing an important break in the stratigraphy. Thickness unknown, but very great.

In the progress of the discussion, the author proposes to install the term "Taconic" in the nomenclature of the older rocks.

1887. The report of this year embodied views evincing positive progress in reference to several questions. The intimate relations of granitic rocks with terranes of admissibly sedimentary origin were brought into distinct view, and many instances of transition were pointed out,* and many remarkable cases of inclusion of granitic and gneissic fragments in the body of the schists, and vice versa. In the report, it was intimated that the Animike formation overlay one eruptive rock and underlay the other, and that it seemed to embrace the Ogishke Conglomerate in its lower portion (p. 381). The lower eruptive rock was represented to be, in some places, a remarkable agglomerate, and in various ways, to become changed to greenish schists, chloritic and sericitic, and to embrace in its mass, generally with an appearance of unconformity, the jaspilyte and iron ore of the Vermilion lake region. At the same time, this green rock exhibited, at times very manifestly, some signs of aqueous stratification. At other times, no such structure was found in it, and it merged into a dense, homogeneous, unbedded, doleritic mass. It was announced that the graywackes, which are in this "green-stone" formation, fade out by merging into its evidently eruptive condition; but in many places are distinctly sedimentary, having much quartz in rounded grains, arranged in unmistakable layers.

It was again pointed out that besides the large body of normal gneiss at the geological base of the series, there is inseparably associated with the gabbro, a red formation, having the apparent composition of syenite; and also a further distinction in the rock of the Giant's range — one portion of it being the result of local change in some bedded sediments probably later than the Laurentian (pp. 347, 349, 352, 353). The cause of this change in the sedimentaries was suggested to be the gabbro eruption. The red syenite resulting is the "red rock" of the earlier reports, the red quartz porphyry and the "Palisade rock" of lake Superior shore. This report contains a geological map of the northeastern part of Minnesota. The distinctions recognized are the following:

1.	Trap and amygdaloid	Cupriferous.
2.	Feldspathic sandrock	
3.	Gabbro and red granite, sometimes dioryte	Mesabi range.
4.	Quartz porphyry and felsyte.	

**Fifteenth Annual Report Minn.*, 1887, pp. 290, 292, 293, 294. 296. See also, the accompanying reports.

5.	Gray quartzyte and black slate	Animike.
6.	Greenstone, diabase and chlorite schist.	
7.	Sericitic schist, argillyte and graywacke	Kewatin (in part.)
8.	Iron ore.	
9.	Conglomerate and conglomeritic felsyte	Ogishke.
10.	Mica and hornblende schist with dioryte	Vermilion series.
11.	Gneiss, syenite, granite	Laurentian?

1888. Questions of taxonomy and parallelism occupy much attention in the report of work for 1887.* A visit to the "Original Huronian" of Sir William Logan leads to the conclusion that while the stratigraphic descriptions of Logan were faithful, the "green chloritic slates," so-called, are not by any means constituent parts of the stratigraphy, but are distinctly eruptive. The "slate conglomerate" of Logan, he thinks repeated in Minnesota, in the Ogishke Conglomerate (pp. 39, 58, 59.) The general parallelism is given as below.

CANADA.	MINNESOTA.
Ottertail quartzyte Thessalon quartzyte	Pewabic quartzyte? New Ulm, Pokegama and Wauswaugoing quartzytes.
Black slate	Animike black slate.
"Lithographic stone" and fine gray quartzyte	(Not known.)
Red felsyte	Felsytes at Duluth, and probably the great Palisades.
Missisagui quartzyte	(Not known.)
Slate conglomerate	Ogishke conglomerate.

Careful observations reported from the region north of Gunflint lake, indicate two conclusions:

1. There is a gradual transition, structural and mineralogical, from the Kewatin downward, through mica and hornblende schist, to the gneiss (pp. 68-70. Also *XVI Rep.*, 37-39.)

2. The intermediate crystalline schists (Vermilion group) do not seem in all places to be present (pp. 74-77, 81.) Room exists for the supposition that the metamorphic action in some regions was sufficiently powerful to carry fused masses of the lower sedimentary rocks bodily across the stratigraphic horizon of the crystalline schists into contact with the Kewatin schists. For this reason, crystalline schists sometimes are interrupted by gneissic rocks.

Of conglomerates in crystalline horizons, he says:

**Sixteenth Minnesota Report*, 1888.

"The conglomeritic structure has therefore now been seen in the following crystalline rocks of Minnesota:

1. The Sauk Rapids "granite."

2. The porphyritic conglomerate at Ogishke Muncie lake, and the similar gneiss in Kekekabic lake.

3. The Stuntz island porodyte.

4. The greenstone of Twin mountain.

5. My brother reports it conspicuous in the Saganaga gneiss.

6. This bowlder [from Iron lake] shows it in the Vermilion group. (Later known in gneiss at Redwood Falls and Morton in the Minnesota valley.)

7. In the Laurentian syenite in Michigan, south of the Aurora mine.*

As to the distinctness of the Animike and Kewatin, the author entertains no longer any doubts, and he cites facts on pages 80 and 81 which prove it, and prove the equivalence of the Huronian of Canada with the Animike. But the upper part of the Ogishke conglomerate he is disposed to regard as a member of the Animike

In traversing the country between Gunflint lake and Ogishke Muncie lake he established the existence of an upper member of the Animike, which was named Pewabic quartzyte. It is magnetitic, and lies near the top of the Animike (pp. 85-86.) He parallelizes the Pewabic quartzyte with:

Wauswaugoning quartzyte.

Thessalon and Ottertail quartzyte (of Ontario.)

Potsdam sandstone of the Adirondacks.†

And these are regarded as further equivalents of the Pewabic quartzyte:

Granular quartz (Emmons)

Teal lake quartzyte, No. III (Brooks.)

Quartzyte group (Rominger.)

Baraboo quartzyte.

Sioux quartzyte (See XVIIth. Minn. Rep., p. 51‡.)

The following is the method of reasoning employed to establish the relations of the Ogishke conglomerate with the Animike:

"The hills about the northeast extremity of Gabimichigama lake consist entirely of Animike, fine-grained, tilted, fractured, rece-

*Many bowlders may be seen in the granite of which the Chicago "Auditorium" is built. According to the writer's observation, few granites can be found without evidence of fragmental intermixture. The granite in the "Auditorium" was taken from the Giant's range, at Hinsdale, Minn.

†On this parallelism see, also, *American Geologist*, March, 1880.

‡In the eighteenth annual report he concludes that the Pewabic quartzyte is below the black slates of the Animike, carrying with it the great gabbro outflow and the red granites and quartz porphyries to the same stratigraphic position.

mented, but in general dipping northeasterly. At the lake shore, these beds weather out very rough, the silicious veins and the harder beds projecting. In some places they are about vertical, but they vary constantly in dip and strike."

"In passing along the north shore westward, however, N. E. ¼ of sec. 31, 65-5, this rock becomes slaty and vertical, and strikes N. W. by compass.

"All along the north shore, from the northeast end of the lake to about the centre of N. E. of sec. 31, 65-5, these titled slates and quartzytes extend, having a high dip toward the northeast, and finally becoming vertical. The shore-line runs across the strike but not at a right angle. Hence in going west, one passes onto lower and lower beds. At this place the Ogishke conglomerate appears on the shore, rising in a ridge about fifty feet high, at a few rods from the shore. On the beach it is disintegrated and hardly preceptible. The dip of the beds of quartzyte and slate that are interbedded with it is 88° N. E. and the strike N. W. *There is thus seen to be an undeniable graduation from the Animike into the Conglomerate.*" (pp. 90-91).

Further evidences of a transition are thought to be present in the disturbed condition of the strata about Fox and Agamok lakes (pp 94-95).

1889. This result, as announced above, is pronounced in the report of work for 1888* an important point reached—"the separation of the Ogishke conglomerate from the greenstone agglomerate, on which in some places it must lie unconformably. They seem to have both been affected by the gabbro epoch of disturbance and the gabbro was found in different localities to lie on the greatly inclined strata of one, and the nearly vertical strata of the other."

This report embraces very comprehensive discussions of the "parallels of the Kewatin," the "possibility of rocks younger than the Kewatin, before the beginning of the Taconic," the "age of the Taconic (Animike Huronian)," and the "age of the Potsdam," all of which must be consulted in arriving at an adequate estimate of aggregate results reached by the author; but it is necessary here to avoid prolixity. Among "problems that need further investigation," the following themes are suggested: Eruptive and sedimentary Laurentian; Planes of hydrothermal fusion, and their relation to the origin of the crystalline rocks; Date of upheaval of the crystalline schists; Nature and origin of jaspilyte; What is muscovado rock ?

*Seventeenth Annual Report, Minnesota, p. 24, 1888.

Toward the close of the report, the following general table of Minnesota rocks is introduced:

CALCIFEROUS. Magnesian limestones and sandstones. ST. CROIX. Sandstones and shales.	Dikelocephalus horizon.
Overlap unconformity.	
POTSDAM. Quartzyte, gabbro, red granite and Keweenawan.	Paradoxides horizon.
Overlap unconformity.	
TACONIC. Black and gray slates and quartzytes, iron ore (Huronian, Animike).	Olenellus horizon.
Overlap unconformity.	
KEWATIN. (Including the Kawishiwin or greenstone belt, with its jaspilyte), Sericitic schists and graywackes. VERMILION. (Coutchiching?) crystalline schists.	Archæan.
Eruptive unconformity.	
LAURENTIAN. Gneiss.	

CARL ROMINGER.

Dr. Rominger's observations and speculative opinions in reference to the older rocks are embodied in a state report upon the Marquette and Menominee iron regions of the Upper Peninsula of Michigan.* Taking up first the Marquette iron district, he conceives it "as a synclinal trough of granite, which by the upheaval of its northern and southern margins, caused the inclosure of the incumbent sedimentary strata between its walls, and their simultaneous uplift and corrugation into parallel folds by the lateral pressure exerted from its rising and approaching edges" (p. 4).

Speaking more specifically, he says of the two series hitherto regarded as Laurentian and Huronian :

By comparing the descriptions of the Laurentian formation as developed in Canada, with the granitic exposures observable in Michigan, or specially in the Marquette district, I cannot see so strong an analogy between them as to identify them without hesitation ; while I endorse the identification of the other group of rocks with the Huronian, although they differ too, in some degree" (p. 5). "I declare at once my serious doubts whether the granites of the Marquette region represent the Laurentian series of Eastern

*Geological Survey of Michigan, Upper Peninsula, 1878-80, accompanied by a Geological Map. vol. iv. 8vo., pp. 248, 1881.

Canada, which I have never had an opportunity to study in the field, but which is represented to be a much older formation, pre-existing as the surface rock before the Huronian sediments began to form, while, according to my own observations, the granites of Marquette are eruptive masses, which came to the surface after the Huronian beds were already formed."

Referring to the discordances between these two systems, frequently alleged by the Canadian geologists, he says :

"As far as my observations go, I have never been able to discover any positive proof of an existing discordance."

Further, in reference to the successional and structural relations of the series, he continues:

"By their eruption, [the granitic rocks] caused not only the great dislocations of the Huronian formation, but the half molten, plastic granite mass induced by their contact with the Huronian rock-beds, also their alteration into a more or less perfect crystalline condition, and commingled with them so as to make it an embarassing task to find a line of demarkation between the intrusive and the intruded rock-masses. The syenitic and gneissic hornblende rocks connected with the granite differ so little from the crystalline hornblende rocks of the Huronian series, that I look at them merely as differently advanced stages in the transformation of the same material. Those nearest to the focus of altering influences are now completely transformed and restored to the domain of the volcanic nucleus ; the more remote strata were less changed, and retained distinct marks of their sedimentary origin ; but if this view is correct, it cannot be expected to find traces preserved of the conformable or non-conformable deposition of the Huronian layers on their substratum" (pp. 6, 7).

He dissents from the subdivisions of major Brooks.

"Beginning below with his groups from I to V, he never made an attempt to define them. * * As to groups VII, IX and XI, certain dioritic outcrops are designated and considered to be regularly interstratified layers in the sedimentary succession, while I have full reason to consider them as intrusive masses, belonging to a lower horizon of the Huronian series, which by volcanic pressure have been forced through or between the incumbent rock-beds wherever a chance for it was offered, and consequently are found, one time in contiguity with this, another time with another stratum as it happened to be the surface rock of the spot. * * Groups XV to XX, intended to comprise a younger series of beds developed in the western part of the Marquette region, are unnecessarily multiplied into vaguely defined subdivisions. Major Brooks identified strata of the Menominee river district as representatives of Groups XV to XX which, lithologically, have no similarity with those of the Marquette district, adding still more to the confusion already existing." Dr. Rominger arranges the Huronian series in the following subdivisions (p. 8).

VI.	Mica Schist Group.	
V.	Arenaceous Slate Group.	
IV.	Iron Group.	[Quartzite Group (p. 71.)]
III.	Quartzite Group.	[Iron Group.]
II.	Dioritic Group.	
I.	Granitic Group.	

The Serpentine group is separately considered.

Before the completion of his report, Dr. Rominger became convinced that his Iron group and Quartzite group ought to exchange places, as shown above in brackets.

Besides the granitic masses bounding the Huronian on the north and south, he says:

"Granites are also found interstraified with the Huronian schists."

Of the character of the granite he says:

"They are usually middling coarse grained, of reddish tints, often composed of a magma of incompletely defined crystals imbedded within a granular interstitial mass rather than of well-formed, completely defined crystals; its fracture is therefore rather generally of a dull lustre. * * The micaceous constituent of these granites, where it does enter into the composition, is rarely well crystallized in brightly shining larger leaves, although it occurs occasionally, but usually has a minutely scaly form and a dark green color approaching to chlorite by gradations, or is replaced by hydromicaceous, fibrous, granular substance, generally called talcose from its soft greasy feel and its lighter color, with partial transparency in thin seams" (p. 15).

In describing gneissoid rocks of this region he says:

"This stratified banded rock, in contiguity with the granite, and alternating with it in parallel belts, often becomes completely entangled with it. The granitic masses intersect the gneissoid, enter wedge-like between them in the direction of the lamination or transversely, inclosing strips of the gneissoid ledges between the loops of the anastomosing granite seams, and, moreover frequently the so intermingled masses are curved into the most curious coils and serpentine flexions, which evinces their almost plastic condition at the time their intermixture took place." (pp. 16, 17.)

Passing to the consideration of the Dioritic group, and repeating his conviction that the granites are the newer, he says:

"One may ask, of what nature, then, was the substratum on which the Huronian sediments were deposited? I answer: Nothing contradicts the possibility of their deposition on a surface of granite already formed; it is even probable to me that it has been so; but, if we reflect upon the high degree of plasticity, and the almost perfect liquefaction which the concerned rocks subsequently underwent, and upon the dislocative forces causing the softened, and necessarily by this softening process, considerably altered, masses to intermingle almost chaotically, we can no more wonder that the traces of the originally existing former relative position of the rocks among themselves are greatly obliterated. The records of these periods in the history of the earth's crust, when oceanic sediments commenced to form, and fell back again within the grasp of the central fire-focus, as we can observe it in this case, are wiped out, and most likely all our efforts to ascertain the existing original conformity or discordance between such rocks will be in vain" (pp. 22, 23).

"The rock series comprised under the name of *Diorite Group* is made up by a large succession of schistose beds of a very uniform character, which are interstratified with massive belts of diorite differing in structure from the minutely granular, almost aphanitic condition, to a coarsely crystalline form, and being in chemical composition almost identical with the schistose beds" (p. 23).

Certain relations of the dioritic masses and contiguous schists are of interest:

"Often we see, as in the above mentioned instances, the schists adjoining a diorite mass completely entangled with it, in a mode which proves a high degree of plasticity of the diorite mass at the time intermixture took place. * * Although the general character of this large series of rock-beds is very uniform, as it regards the chemical composition, still, an endless number of variations in their structure is produced by the different degrees of metamorphism to which these once indubitably sedimentary rock-beds were subjected" (p. 34).

It will be remembered that major Brooks had admitted the existence of two horizons of iron ore. This was because at Negaunee and the vicinity, a quartzyte was found in a relation of infraposition to the ore-bed, while in most of the mines of the district, a quartzyte was seen reposing above the local ore-bed. These phenomena were supposed to indicate the existence of an ore-bearing horizon above the quartzyte and another below it. Dr. Rominger undertakes to prove that only one ore-horizon exists, and that the normal position of the quartzyte is above. Major Brooks was also under the necessity of assuming two quartzytes, Nos. XIV and V, the latter, or Teal lake quartzyte, being, according to Rominger, identical with the former, and its actual relative position being "the result of an overturn of the strata." (pp. 71, 72, 89.)

Lithologically, he adds:

"The quartzites covering the ore-bearing ledges are compact, dark-colored by hæmatitic pigment and by intermingled granules of martite. The inferior strata are almost regularly brecciated and intermingled with ore-fragments. In the pits of the Cleveland mine, south of the Houghton and Ontonagon Railroad, these brecciated quartzites are immediately underlaid by a fine seam of specular ore which itself, is on its surface, of brecciated structure. This ore-bed is underlaid by a series of light greenish or grayish colored, silky-shining, hydromicaceous schists impregnated with small martite crystals, which on their part, repose on the red, jasper-banded lean ores with inclosed seams of granular and slaty specular ore. In the pits north of the railroad, the quartzite is generally underlaid by chloritic schists inclosing locally quite large octahedrons of martite. Below them usually follows a valuable seam of specular ore, schistose chloritic beds again, and then mixed, jasper-banded, lean ores, with other interstratified seams of ore, partly in the granular form, partly as a slate-ore; lowest, resting on dioritic schists are, in the New York mines, fine-grained, silky-shining, dark, gray-colored argillites, charged with minute granules of martite more or less abundantly," (pp. 81-82).

The "*Arenaceous Slate Group*" of Rominger is generally incumbent on the quartzyte formation; but where this is wanting, it rests on the iron ore formation; and if this also is absent, it rests directly on the dioritic series. According to these statements a break exists between the epoch of the quartzyte and that of the Arenaceous Slate (Compare also, pp. 113, 114, 115.) These strata appear sometimes as "a thick belt of black, fine-grained, slaty rock-beds, interlaminated with silicious sandy seams. * * Next south of these slates are high walls of massive, light colored quartzites in direct conformable contact with them," (p. 105).

In other localities, the group "consists of sandy, somewhat micaceous flagstones, or of finer-grained, banded, silicious rock-beds all more or less impregnated with protoxide of iron as a coloring-matter, and with granules of magnetite, (p. 108). Elsewhere they are clay-slates more or less silicious, (pp. 112, 113); or "black magnetic flags interlaminated with slaty and arenaceous seams," (p. 117).

At a locality in the valley of the Carp river this series has "in part, a conformable northern dip with the quartzites, but frequently also, a southern dip is observed; though the direct contact of the two formations" is concealed by Drift, (p. 106).

This Arenaceous Slate group occupies the surface over a large area on the north of the dioritic belt which abuts on lake Superior at Marquette; and over another area on the south of the dioritic belt. It is believed by Dr. Rominger to be of the same age as the slate formation in the district of L'Anse and Huron bay, between Marquette and Keweenaw point. *The thickness of the latter slates "is enormously great." In color they range from dark to blackish, are partly hard and silicious, of bedding and cleavage too irregular for roofing, but are also in part, regularly laminated, of an agreeable black color, and well suited for roofing, (vol. iii, p. 163). Locally, however, the Huron slates vary to "whitish-gray-yellow, red and brown." They possess all degrees of hardness. The cleavage appears often coincident with the sedimentation, but where the colored bands are preserved, they are seen to make an acute angle with the cleavage. The sedimentary dip is northward. The formation presents three divisions: An *upper* of lighter colored, variegated slates; a *middle,* of alternating slaty and arenaceous beds, with interstratified, larger, compact quartzyte belts of light color and partly blackish; and a *lower* division embracing the roofing-slates, (vol. iv, p. 130). The middle division is regarded as equivalent to the Arenaceous Slate group of the Marquette district. It is likewise an instructive coincidence that a higher horizon of iron-ore occurs in both regions, of which the Taylor mine is an example in the L'Anse district, and the Northampton and d'Alaby mines (north of the Champion mine) are examples within the Marquette district. The ore occurs above the black slates, which in the Marquette district are graphitic. These ore deposits are regarded as contemporaneous with that of the Commonwealth mine in Wisconsin† (pp. 130, 222-227).

The rocks of the Mica Schist group of Rominger are described as "a sub-porous ground-mass of very minute granules of white, translucid quartz in intermixture with a large proportion of bright-

*Dr. Rominger's earliest observations on the L'Anse slates are found in *Geology of Michigan*, vol. iii, pp. 159-166. His later views are in vol. iv, pp. 129-130.

†This is the view of major Brooks, recorded ante' p 174. The reader cannot fail to compare the description of these slates and their accompaniments of quartz-schist and iron-ore, with the published descriptions of the Animike series. See, especially, ante' pp. 176-184. For further description of the Commonwealth mine, see C. E. Wright, *Geology of Wisconsin*, vol. iii, pp. 678-684. Compare also, Eagle mine, Wisconsin.

ly glistening black mica scales, and not rarely also, with chlorite" (p. 131).

The mica is sometimes silvery, and the schists are interlaminated with large belts of a more compact, minutely granular, sub-porous quartz rock, not so rich in the micaceous constituent, but often mingled with curved greenish crystals of actinolite.* In some conditions this formation reveals a distinct sedimentary striation (pp. 132, 133).

Dr. Rominger is not able to reach a satisfactory solution of the genesis of the Serpentine group.

"The hypothesis that the Serpentine formation is the product of local metamorphic influences on the dioritic series [by which it is surrounded], is very improbable, as the lithological character of the two contiguous rock-species changes abruptly." "The rocks occur generally in bulky, non-stratified masses which, if they ever originated from mechanical sedimentary deposits, are by chemical action so completely transformed as to efface all traces of their former detrital structure. They resemble a volcanic eruptive rock, forced to the surface in a soft plastic condition; and most likely heat was one of the prime agents in their formation, or else transformation in combination with aqueous vapors—which is suggested by the hydrated composition of the serpentine" (p. 135).

A study of the Menominee iron district led to the determination of the following groups of rocks (p. 182).

III. *Lake Hanbury Slate Group.* Dark-gray, slaty or schistose beds, with interlaminated quartzose belts. Thickness over 2,000 feet.

II. *Quinnesec Ore Formation.* In the *upper* part, light red, whitish or gray, hydromicaceous and argillitic strata. In the *lower* part, silicious beds richly impregnated with iron oxide in the amorphous, hæmatitic condition, or in the crystalline form of martite, with metallic lustre, and inclosing beds almost exclusively of martite granules. The valuable ore deposits. 1,000 feet.

I. *Norway Limestone Belt.* Light-colored quartzyte and silicious limestone, usually in part of a brecciated structure. 1,000 feet.

The rocks along the Menominee river are regarded as equivalents of the Diorite Group of the Marquette district, and decidedly *not* representatives of Nos. XV–XX of major Brooks.

*Evidently this is not a proper "mica schist," but rather a micaceous quartzyte or a micaceous quartz schist. It can scarcely be compared with the "tender" mica schists of Hunt's Montalban, though the horizon is nearly coincident.

In general, the comparison of the Marquette and Menominee districts, in spite of Dr. Rominger's deprecation of tabular parallels, may be best shown by the following table (pp. 240-241):

	MARQUETTE.	MENOMINEE.
V.	Ore deposits of the Taylor, S. C. Smith, d'Alaby and Northamton mines. Actinolite schists above quartzytes of Michigammi and Spurr mines.	Commonwealth and related ores. Actinolite schists.
IV.	Quartzyte Group (Teal lake). Limestone in juxtaposition.	Quartzyte of Sturgeon river falls. Limestone separated by an interval.
III.	Iron Group.	Quinnesec Iron range.
II.	Dioritic Group. Intrusive Granites.	Diorytes and schists of Menominee river. Felsyte Porphyry, Pemenee Falls.

ROLAND DUER IRVING.

1877. In his annual report for 1874, made to Dr. I. A. Lapham, state geologist of Wisconsin,* the "Copper-bearing Rocks" were made by professor Irving, a distinct division in the geology of the northern part of the state, holding a position between the Huronian and the Potsdam sandstone. He showed also the existence of a synclinal axis in Wisconsin, in continuation of the great trough between Keweenaw point and Ile Royale.† He held, *first*, that the beds of the Copper-bearing series and those of the Huronian were once spread horizontally over one another, including the whole series of tilted sandstones on the Montreal river; they were disturbed by the same force, and receiving their present tilted positions at the same time, as evinced by the entire conformability of the two series. *Second.* The horizontal sandstones of the Apostle islands and the west side of lake Superior were laid down subsequently, and after an immense amount of erosion; and the sandstones of eastern lake Superior were formed at the same time. *Third.* The Copper-bearing rocks should rather be classed with the Archæan than with the Silurian.

The Baraboo and related quartzyte masses lying in Wisconsin, many miles south of the principal Archæan area, have been differently viewed by different geologists, some regarding them as of Huronian age,‡ and others, as the representatives of the Potsdam sandstone,§—the Wisconsin sandstone so described, pertaining as

**Geology of Wisconsin*, Survey of 1873-1877, vol. ii, p. 47, 1877.

†This view was earlier set forth in *Amer. Jour. Sci.*, III, viii, 45-56, 1874.

‡J. Hall, *Geology of Wisconsin*, 1862; Irving, *Amer. Jour. Sci.*, III, iii, 93-99; *Geology of Wisconsin*, ii, 504-524; Chamberlin. *Geol. Wis.* ii, 248-256.

§Percival, *Annual Report Geol. Surv. Wis.*, 1856. p. 101; A. Winchell, *Amer. Jour. Sci.*, II xxxvii, 226; J. H. Eaton, *Wiscon. Acad. Sci.*, Feb. 1871.

they think, to a higher horizon. Professor Irving, as early as 1871, announced his conviction of their Huronian age; and in the Wisconsin report, he worked out the evidences with fullness. The quartzytes are differentiated from the contiguous sandstone by lithological characters and abrupt structural unconformability; and the only weakness in professor Irving's position is the lack of full proof that the sandstone is the true equivalent of the Potsdam.*

1880. The third volume of the geology of Wisconsin reveals his masterly grasp of the geological structure of northern Wisconsin, and of the genesis and history of the rocks which underlie the region. Here are presented in bold and confident outline, those interpretations, bordering sometimes on speculation, which characterized the leading discussions which occupied him until removed by an early death. His writings are so voluminous, however, that it will not be practicable to do more than set forth his positions on some of the great questions with which he grappled.

In reference to the nature and origin of the Laurentian rocks, which he fully parallelized with the Canadian Laurentian (iii, 5), we find him using the following language:

"The prevailing rock along the northern border [of the northern mass] is a dark gray to black hornblende gneiss, in which the hornblende has usually been more or less altered to chlorite. This alteration, when carried to any considerable extent, gives a greenish tinge and greasy feeling to the rock, and in cases of extreme alteration, there is a passage to a green chloritic schist. The associated granites are usually light pinkish-tinted to gray, and highly quartzose, a frequent gneissoid tendency showing their sedimentary nature," (iii, 6).

"The hornblende gneiss is always very plainly laminated, frequently highly schistose and the whole internal structure of the rock, as seen under the microscope, shows conclusively its original clastic condition. The granites are generally without such distinct bedding but appear nevertheless, to be true metamorphic granite. No eruptive granite, recognizable as such, has been observed. It is not possible, without overstepping the limits of our district, to reach any important generalizations with regard to the Laurentian series. It is evident enough that the rocks are of a true sedimentary origin, and that they have been folded in an exceedingly intricate manner," (iii, 93).

In still another place, professor Irving records views in this connection, which possess interest:

*This equivalency has been earnestly contested in writings by N. H. Winchell, already quoted. See. anté, pp. 175.

"The term igneous, as used by Mr. Wright, who seems also to hold to the unwarrantable theory that the original rock of the earth's first formed crust would be granite, is one not applicable to any granites, since even in the case of the exotic kinds, the relation of the constituent minerals disproves a true igneous origin. The quartz of granite is always the last formed mineral, whereas, from its infusibility, it would certainly be the first to form in cooling from a state of fluidity. All the facts go to show that the intrusive granites are but sediments softened by what has been termed aqueo-igneous fusion, to a degree of plasticity sufficient to allow of their penetrating fissures in the adjacent formations. The intrusive or exotic granites and the metamorphic or indigenous granites have thus had about the same origin, and there are no lithological characteristics whatever, either microscropic or macroscopic, by which we can distinguish them in specimens," (iii, p. 194, note).

At a later date, professor Irving recorded his views as follows:

"This stratification [of gneiss], or parallel arrangement of its ingredients, is commonly believed to have been caused by the process of sedimentation, the crystalline texture now shown by the gneiss and all other crystalline schists being regarded as the result of a peculiar process of molecular arrangement known to geologists as 'metamorphism.' While it seems very probable that there is a great deal of truth in this view, the theories of metamorphism as they now stand, are very unsatisfactory. Many rocks which have been called metamorphic are plainly of an eruptive origin, and it seems not improbable that the same origin is to be attributed to some rocks with a strongly developed schistose structure." *

Of the Huronian system he remarks:

"Lying immediately against the Laurentian, and very sharply defined from it, we find, extending from the Montreal river westward for fifty miles, to lake Numakagon, a belt of schistose rocks which we refer unhesitatingly to the Canadian Huronian, and which are beyond question, the direct westward extension of the iron-bearing series of the Upper Peninsula of Michigan," (iii, 6).

The subdivisions of this belt are recognized as follows, (iii, 6):

5. Medium-grained to aphanitic, dark gray mica schists, with coarse intrusive granite. 7,985 feet.

4. Alternations of black mica slate with dioryte and schistose quartzytes, and unfilled gaps. 3,495 feet.

3. Tremolitic magnetite schists, magnetitic and specular quartzytes — forming the Penokee Iron range. 780 feet.

**Geology of Wisconsin*, vol. i, p. 352, 1883.

2. Straw-colored to greenish quartz-schist, and argillitic mica schist, often novaculyte. 410 feet.
1. Crystalline tremolitic limestone, at times overlaid by a band of white arenaceous quartzyte, and at times absent, the next formation above them coming into contact with the Laurentian. 130 feet.

As the identification of the Penokee series with the Huronian is still a subject of debate, professor Irving's affirmative reasons possess interest:

(1). There appears to be a direct continuation with the iron-bearing system of the Marquette region of Michigan; (2). The grand subdivisions of the Bad river [Penokee] and Marquette systems are strikingly similar; * (3). The Bad river and Marquette systems both show the same relation to the Laurentian and Keweenawan systems as found in the Huronian of Canada; i. e. are newer than the former and older than the latter; (4). The Marquette system is found in unconformable contact with the Lower Silurian red sandstone of lake Superior, and also in the Menominee region, is also found in unconformable contact with the fossiliferous Primordial sandstones of the Mississippi valley (iii, p. 7).†

The boldest feature of the views promulgated at this time, was the characterization of the "Keweenawan System," a step foreshadowed in 1877, and evidently meditated since 1874. This widely extended Michigan-Wisconsin system is thus described:

"It is a distinctly stratified system, but is in large measure made up of eruptive rocks in the form of great flows. These appear to constitute in Wisconsin, the lower ten thousand to thirty thousand feet of the system, apparently without interstratified detrital beds. Above these, we find the detrital beds increasing in frequency, until they seem to exclude the igneous rocks altogether; the upper portions for some fifteen thousand feet, being apparently composed wholly of sandstone and shale, with a heavy mass of conglomerate at base" (iii, 7).

These rocks in northern Wisconsin, form a true synclinal depression, and the Chequamegon bay lies within it, but crowded over to the northern side. The eruptive rocks of the system are chiefly of the augite-plagioclase kind—hornblende when occasion-

*The stratigraphy of the Penokee Range is given in *Amer. Jour. Sci.* III, xvii, pp. 394-395 and *Geol. of Wis.*, iii, p 450, table, and in full detail in the same volume, pp. 103-166. On the "Mica Schists and Black slates," see Van Hise, *Amer. Jour. Sci.*, III, xxxi, 453-459, 1886. On the "Iron Ores" of the series, see Van Hise, *Amer. Jour. Sci.*, III, xxxvii 32-48, 1889. On their "Origin" see Irving, *Amer. Jour. Sci.* III, xxxii 255-272, 1886.

†This identification had been announced previously by Irving in *Amer. Jour. Sci.*, III, xvii, 393-398, 1879. Further on the "Divisibility of the Archæan in the Northwest," see Irving, *Amer. Jour. Sci.*, III, xxix, 237-249, 1885.

ally occurring, being always a paramorphic product of the augite. These eruptives, therefore present a marked distinction from the hornblende-bearing eruptives of the Huronian ; and belong to the Rosenbuschian categories, diabase, melaphyr and gabbro. The diabases, which are far the most abundant, occur in distinct beds of overflow, each of which (as first pointed out by Pumpelly and Marvine) is amygdaloidal above, and massive, often columnar below, with an intermediate zone, which Pumpelly designated "pseudo-amygdaloidal." The gabbros are coarse grained, and two varieties are distinguished, the most common being light to dark gray and perfectly crystalline, and the other being red and black mottled, or red and gray mottled, with some of the crystals dulled in appearance, or red-stained by iron infiltration (iii, 10).*

1883. In the progress of these studies, professor Irving devoted much attention to the subjects of paramorphic changes and secondary enlargements in the mineral constituents of rocks ; and while not by any means the first to bring these facts to light, he was foremost in extending our knowledge of them, and in illustrating their importance in the history of the rocks. He alludes to the fact that most of the older, dark basic, massive rocks have been called diorytes, because hornblende is joined in them with a triclinic feldspar, while augite seldom occupies the same place. But he says:

"Precisely the reverse of this is the case, the diabases, in fact, being the common kinds, while diorites are everywhere rare. Moreover, in many diorites entitled to be so called by their content of hornblende as a chief constituent, this mineral has been proved to be merely a secondary transformation of augite, remnants of which are here and there to be seen in little cores." †

This, he says, is true of all the diorytes which he had studied in this section, and he entertained little doubt that the same would be found true of the diorytes described by Wichmann from the Menominee region. Hence he concludes that no dioryte as an original rock, has been found in Wisconsin.‡

The work on the Wisconsin survey having closed, professor Irving entered upon a great undertaking, under the auspices of the United States Geological Survey. This was the preparation of "a memoir aiming at a general exposition of the nature, structure and

*This series of beds had in 1873 been named "Keweenaw Group," by T. S. Hunt, (*Trans Amer. Inst. Mining Eng.*, 1, 331-342) ; and in 1875, "Keweenawian," by Brooks. Later "Keweenian," the more euphonious form of the name, was proposed by Hunt (Harper's *Annual Record,* 1876). See *Geol. Wis.*, iii, 660. Removing superfluous letters, there remains "Kewenian," the best form of all.

†*Geology of Wisconsin*, vol. i, p. 345, 1883.

‡What is true in Wisconsin is very likely to be true also in Michigan.

extent of the series of rocks in which occurs the well-known native copper of lake Superior." The transmission of this memoir bears date October 25, 1881, but the title page is dated 1883.*

This remarkable work is an amplification of views, and strengthening of positions relating to a newly recognized geological system which in the Wisconsin report had been defined as Keweenawan.† It is not intended to give any synopsis of this volume, nor to point out the excellencies of the treatment; but a few of its more important positions will be stated.

The Lower Group of the Upper Copper-bearing series of Logan —the "Animike" of Hunt—is excluded from the system; but the white and red dolomitic sandstones, in the peninsula between Black and Thunder bays, and thence to lake Nipigon, are included. The horizontal sandstones which form the south shore east of Bete-Grise bay on Keweenaw point, and westward from Clinton point, Wisconsin, are also included. The system, then, "consists of the succession of interbedded traps, amygdaloids, felsitic porphyries porphyry-conglomerates and sandstones, and the conformably overlying thick sandstone, as typically developed in the region of Keweenaw point and Portage lake, on the south shore of lake Superior," (pp. 24, 385).

The volcanic theory of the origin of pebbles forming the conglomeritic beds is combatted. This theory had been promulgated by Houghton in 1841, and Foster and Whitney, in 1850 and 1854.‡ The system is demonstrated to be unconformable with the Huronian below and the Silurian above.

The possibility of a sedimentary origin for any of the stratified semi-amygdaloids§ of the Agate Bay group of beds is "absolutely excluded by the completely crystalline interior texture, the highly vesicular character, the presence of unindividualized magma, the microscopic flowage structure, and the graduation of each bed downward into vertically columnar, non-vesicular olivine-diabase,

*U. S. Geological Survey, Clarence King, Director. "The Copper-bearing Rocks of Lake Superior," 4to, pp. 464, with maps and cuts, 1883. [Being Monograph V.] A full digest of this memoir is contained in the *Third Annual Report* of the U. S. Geol. Surv. pp. 93-198. *Bulletin No. 23, U. S. Geol. Surv.*, 1885, pp. 124, by R. D. Irving and T. C. Chamberlin, is an important supplement to this memoir.

†This system is set forth in an elementary way suitable for the general reader, by T. C. Chamberlin, in the first volume of the *Wisconsin Report*, pp. 96-118, 1883.

‡Wadsworth also states that Foster and Whitney "remain the best and most accurate exponents of the geology of the country." (*Bull. Mus. Comp. Zool.*, vii *Geol. Ser.*, i, pp. 13, 131); and would thus seem to approve this leading position; yet, without noting his divergence from them, he says: "These conglomerates and sandstones show by the rounded and water-worn character of their constituent pebbles and grains, that they are beach deposits," (*id.*, p. 128).

§Noticed by N. H. Winchell, anté, p. 177, and called by Norwood, "metamorphic hales."

(pp. 138, 287)*. The forms of the "Sawteeth mountains" he refuses to attribute to faulting, and says:

"The case is just such as is found in every region of flat-dipping, hard rocks, and especially where softer layers are interbedded, as in this case," (p. 142).

He regards the dikes seen along the Minnesota shore as sources of the flows of the lake basin ; and antagonizes Dr. Selwyn's suggestion of activity through a single vent (p. 144). The "Palisade rock," he says, "is shown under the microscope, to be a quartz-porphyry, with no traces of a clastic nature (p. 187). The central mass of the Porcupine mountains is a quartzose porphyry unquestionably eruptive. Their structure has so much in common with that of the laccolitic mountains in southern Utah, that they might be supposed to owe their existence to an eruption of the porphyry of their central portions. * * But these mountains, he concludes, "owe their existence, in all probability, to a fold, the porphyry of the central portions being one of the usual embedded masses laid bare by subsequent denudation" (pp. 150-1).† He takes the position, and repeats it many times, that the so-called Animike slates are "beyond question, the equivalents of the iron-bearing Huronian of the south shore" (p. 157).

Of the "red rocks" so largely associated with the gabbro of Duluth, he says:

"They lie in it very irregularly, and form nothing like distinct belts, so far as I could make out. They may be seen in great patches hundreds of feet square, and surrounded on all sides by the gabbro, and again, as at the quarry near Rice's Point, in irregular series, from two or three inches to several feet in width. Much the most abundant kind of these red rocks is one which presents macroscopically a wholly crystalline texture and a pinkish color mottled with green. Pink feldspar facets, now and then striated, quartz, and a greenish mineral, may all be made out with the naked eye. Under the microscope, the rock is seen to be chiefly composed of reddened orthoclase ; greenish hornblende, quartz and magnetite are also present. The quartz occurs both in quite large patches, and again in little strings running through and through the feldspars, in the usual manner of secondary quartz. A number of these small patches of quartz lying near each other will polarize together, showing that they are part of one individual. Moreover, the same is true of the larger quartz areas, and numbers of small

*On *a priori* grounds, one might expect unindividualized magma to remain in sedimentary rocks when not completely changed.

†See detailed description, pp. 209-225.

particles lying near them, so that all of the quartz is considered to be secondary. This secondary quartz is frequently scattered through the feldspars in such a manner as to present the appearance of graphic granite, and again it is arranged in irregularly radiating lines. Chlorite is often present as an alteration product of both feldspars and hornblende. No base finer than the rest of the rock was observed, so that the name should apparently be syenite" (pp. 270-1).

Another variety of the "red rock" is described as true granitic porphyry. A rarer variety is a felsitic porphyry. These are all regarded as phases of the same rock.

In describing the Animike rocks in the vicinity of Thunder bay, lake Superior, he sums up by saying that they "consist of a great series, probably upwards of ten thousand feet in thickness, of quartzites which are often arenaceous, quartz-slates, argillaceous or clay slates, magnetic quartzites and sandstones, thin limestone beds, and beds of a cherty and jaspery material," (p. 379). He says also:

"Logan moreover, evidently took as Huronian, that part of the Animike group which 'occupies the coast for a distance of ten miles immediately below the mouth of the Kamanistiquia river, on the north side, leaning in a narrow strip, against the gneiss of the older series,'" (p. 379).

The Animike rocks are confidently identified with the rocks of the Penokee Range; but these latter, as has been stated, were with equal confidence identified with those of the iron-bearing series of Marquette. The Animike must therefore be the equivalent of the Marquette rocks. But Irving endeavored to trace some positive resemblances between the Animike and the rocks of Marquette; but without very convincing results, (pp. 385-6).

At this point the able author is seen to be on the brink of a broad fallacious inference. He takes up the consideration of the "Original Huronian," and correctly concludes:

"It appears to me very probable that the original Huronian of lake Huron and the Animike slates of Thunder bay, and thence southwestward to the Mississippi river, are one and the same formation," (p. 390).

This was the opinion first entertained by Logan;* but he subsequently associated those slates with the overlying Keweenawan. Then, as there was a lower, unconformable mass of slate conglomerates, he concluded to call those Huronian. Irving, however, while still holding to the Huronian character of the Animike,

Report of Progress, Geol. Surv. of Canada, 1844, p. 29.

seems to have disregarded the vertical slate conglomerates, apparently because they graduate conformably into the crystalline schists and gneisses, and might be taken for a portion of that series —an unconformability between two systems supposed Huronian and Laurentian, having been noted at Penokee gap. Thus Irving held as Huronian what Logan held as a part of the Copper-bearing series; and Logan came to hold as Huronian what Irving took as part of the crystalline schist series. But when Logan based his description on what he now held to be Huronian and Irving overlooked, Irving thought them to apply to the iron series of Vermilion lake (as they readily did), and concluded that to be Huronian, though in truth the rocks graduated into the crystalline schists, while what he had rightly identified with Huronian on Thunder bay, was really an overlying and discordant series. But that discordance Irving had not yet discovered at any actual juxtaposition, and he devoted much effort to showing how two different formations of different dip and strike, might, at some former time, have approached each other with a common dip and strike, (pp. 392-4). In this state of the facts professor Irving feels himself in a dilemma when he reads Dr. Bell's descriptions of assumed Huronian rocks more remote from Thunder bay, and misunderstands Dr. Bell at the same time, as speaking of the rocks which *Irving* had correctly called Huronian. Nevertheless, Irving is able to convince himself that all the areas by anybody called Huronian, agree in such particulars as to justify him in sweeping them all into that category, (p. 395). Irving suspects indeed, that two groups of schists have been confounded by the Canadian geologists—"the iron-bearing schists of the Huronian and the schistose greenish phase of the older gneiss"—but he does not suspect that he has himself identified and confounded two other systems which, unlike these groups, stand in discordant mineralogical and structural relations to each other.

1885. The overlap of professor Irving's Keweenawan studies on systems of older date, was the prelude to a formal investigation of the Huronian system as a specialty. This was undertaken also, under the auspices of the Government survey, and was in progress at the date of his lamented death. But some preliminary papers appeared, from which we may learn the fundamental positions which he was preparing to defend.* In the first memoir, the following areas of older rocks are grouped together under the designation Huronian:

*A first paper entitled "Preliminary Papers on an Investigation of the Archæan Formations of the Northwestern States." was published in the *Fifth Annual Report* of the U. S. Geol. Surv., 1885, pp. 175-242.

The Original Huronian.
The Marquette-Menominee Iron-bearing schists.
The Wisconsin Valley slates.
The Penokee-Gogebic Iron-bearing schists.
The St. Louis, [Minn.] slates.
The Chippewa Valley quartzites.
The Black River Iron-bearing schists.
The Baraboo quartzites.
The Sioux quartzites.
The Animike series.
Folded schists of Canada.

In the progress of a condensed examination of these eleven areas, professor Irving states more explicitly, what he intimated in his previous memoir, that the so-called "crowning overflow," resting on the Animike cliffs of Thunder bay and the regions to the southwest, is not to be regarded as one final overflow, but a succession of overflows, interbedded in a succession of slaty deposits.* He opposes sharply the position of Foster and Whitney, and later, of Wadsworth, that the iron deposits and associated jaspers are of eruptive origin (p. 192). The folded schists north and east of lake Superior, described by the Canadian geologists, since 1863, as Huronian, are admitted, at least some of them, in that system, but he says:

"We are immediately confronted with a structural problem of a good deal of difficulty, *i. e.*, the relation of these folded schists to the unfolded Animike series. Generally as the Animike series is traced toward its northern border, it is found to lie against a belt of granite and gneiss. This is so along the shore of Thunder bay, and thence westward to Gunflint lake, and it is true again at the Mesabi Range and Pokegama falls district, in Minnesota. North of this belt of granite, comes the belt of folded schists. The appearance thus presented is at first sight, one of general unconformity between the flat-lying Animike and an older series including gneiss and older folded schists."

This state of facts was in direct conflict with his theory that the Animike and the folded (vertical) schists are one. The reconciliation of the facts and the theory occupied his earnest attention. A hypothesis was proposed for this purpose.† He supposes "that the Animike rocks were once continuous with the folded schists to the north of them, and that they are now separated merely because

*P. 203. See also, *Fifth Annual Report*, p. 382. The "crowning overflow" is now discredited by the present Director of the Canadian Survey—*Science*, ii, p. 675, 1884.

†*Third Annual Report, Wisconsin Geol. Surv.*, p. 171; *Monographs U. S. Geol. Surv.*, vol. v. pp. 399. 417; *Fifth Annual Report*, p. 206.

of the erosion of the crowns of the folds between them, the close folding of the folded schists being supposed, on this view, to have been produced concomitantly with the broad simple bend which forms the trough of lake Superior. On this supposition, the unfolded schists of the north shore are compared with the unfolded Penokee of the south shore; and the folded schists of the national boundary, with the folded schists of the Marquette and Menominee regions. All are supposed to represent a great sheet of Huronian deposits once continuously spread upon a floor of far older gneisses and schists, which have since been brought to view by folding and denudation."*

Some little support for this not impossible hypothesis, was gathered from the fact, that in one region, where the horizontal and vertical schists were separated by only a few miles, the horizontal schists acquired considerable dip. In some localities, as shown by N. H. Winchell, they became irregular in dip, and manifestly disturbed. But professor Irving was never able to proceed further.†

In the sequel of this memoir, the author presents other results of studies upon his general problem, and among them are interesting facts respecting enlargements of quartz fragments (pp. 229-230); and these lead him to an explanation of so-called "crystalline sandstones". (p. 219)‡ A final conclusion from these studies is "that all of the quartzites marked provisionally as Huronian on the accompanying map, including the type Huronian of lake Huron, are merely sandstones which have received various degrees of induration by the interstitial deposition of a silicious cement which has generally taken the form of enlargements of the original quartz fragments, less commonly, of minute, independently oriented areas, and still less commonly, of an amorphous or chalcedonic silica, two or even three forms of the cementing silica occurring at times together in the same rock" (p. 236).

**Fifth Annual Report, U. S. Geol. Surv.*, pp. 206-207.

†The writer will here state that the Minnesota Survey has shown that the disturbances referred to (east of Ogishkemuncie lake) are very local, and the horizontal schists north of Gunflint lake are not separated from the vertical by a gneissic interposition, but rest in very discordant contact upon them. No more speculation is necessary.

Professor Irving read a paper before the *National Academy*, Apr. 22, 1887, which was published in *Amer. Jour. Sci.*, III, xxxiv, 204-216; 249-263; 363-374, entitled, "Have We a Huronian Group?" This was chiefly an occasion for restating the views presented in the paper here noticed, and for a final effort to elucidate his hypothesis for the synchronization of the Animike and the older schists now known as Kewatin. This paper has been noticed by me in *Bull. Geol. Soc. Amer.*, i. p. 387.

‡The subject has been more fully treated in *Bulletin U. S. Geol. Surv.*, No. 8, 1884, by R. D, Irving and C. R. VanHise.

Such enlargements in "Hornblendes and Augites" have subsequently been described by professor C. R. VanHise, *Amer. Jour. Sci.* III, xxxiii. 385-388, 1887.

The subject of enlargements of feldspar fragments is similarly discussed and the facts established.

A final conclusion from all the facts is that the most of the rocks generally styled Huronian do not properly fall under the head of metamorphic rocks.

These inferences are carried further in the important Bulletin cited above.

1888. The last important memoir from Professor Irving's pen is a compilation of fundamental principles to be employed in the classification of unfossiliferous rocks.*

Of this the author says: "Beyond many of the facts cited in illustration, and the mode of presentation, the paper does not contain very much that is new or original." It nevertheless presents a convenient synopsis of principles, and shows a mature mastery of the subject. For the present purpose a few quotations of new or maturing views on certain points, will suffice. Speaking of the green schists which with more or less of mica schists and other later rocks has been marked as Huronian for the entire region north of lake Superior by the Canadian survey, he says they are not separated from the Laurentian by any unconformity. Therefore, "The name Huronian belongs to an entirely different group."†

In attempting to illustrate the structural relation of the Animike series to the underlying schists, he presents (p. 421) a diagram section across Gunflint lake, which sets forth the observed facts with sufficient accuracy. But his interpretation of the fact seems to be erroneous. He says the Animike abuts "against an older formation of granite and schists," and he says too, "the iron-bearing horizon at the base of this succession [the Animike] is lithologically identical with that of the Penokee series of northern Wisconsin and Michigan." So far he is perhaps, right—but, with the understanding that the "granite" [gneiss] is quite removed from the *contact* with the Animike, and that the "schists" *at* the contact are not the usual crystalline schists which succeed the gneiss and granite, but hold a position superior to them, in the same vicinity. Professor Irving's misconception consisted in regarding those vertical "schists" as part of the series of crystalline schists, and in conceiving them as different from the vertical schists which inclose the iron ores at Vermilion lake. Identifying these vertically-standing ore beds with those in the flat-lying Animike, he makes

*"On the Classification of the Early Cambrian and Pre-Cambrian Formations. A brief Discussion of Principles, illustrated by examples drawn mainly from the Lake Superior Region." *Seventh Annual Report* U. S. Geol. Surv., 1888, pp. 363-454.

†Yet this is precisely the group which in the Vermilion region of Minnesota, professor Irving calls Huronian

an unsuccessful attempt to represent them as "flat-lying," like the Animike ores at Gunflint lake* (p. 421).

Professor Irving insisted on a "structural unconformity between the Huronian and Laurentian." He makes numerous references to Sir William Logan's utterances on the subject, and though they are strikingly self-contradictory, Irving asserts, they "show certainly his full belief in such unconformity" (p. 430). This confusion on Logan's part, and misapprehension on Irving's, arise from their common error in applying the name Huronian to two different systems, and Irving's supposition that the Penokee Huronian—rightly identified with the original Huronian—is the same as Logan's "Lake Superior Huronian."

In discussing the taxonomic exhibit which he gives of the older rocks (pp. 440-441) he says:

"At the base of the succession is a series composed of gneiss and granitic rocks, with also a large development of schists. The granite is certainly in the main eruptive. The schists are very largely compressed eruptives, but also in part of sedimentary origin" (p. 442). This view may be compared with those given, anté, p. 197.

But of the mica schists or mica slates described as holding a position near the top of the Marquette iron series, he says:

"Our own microscopical studies of them have demonstrated their derivation by mere metasomatic changes, from rocks wholly of detrital origin, the fragmental character frequently being well preserved, even to the naked eye, while large portions of the same horizon show little change from the original fragmental conditions." (p. 386.)†

As the outcome of the entire discussion, professor Irving presents the following taxonomic suggestion (p. 454):

Systems.	*Groups.*	*Systems.*
Paleozoic.	Carboniferous, Devonian, Silurian, Cambrian.	Paleozoic.
Agnotozoic or Eparchæan.	Keweenawan, Huronian, (Other groups?)	
Archæan.	Laurentian (including upper Laurentian.)	Archæan.

* His diagram attempting this is in *Amer. Jour. Sci.*, III, xxxiv, p. 259.

† Such micaceous schists are what the writer, in the Fifteenth and Sixteenth Minnesota Reports, has styled "nascent mica schists."

ANDREW C. LAWSON.

1886. In his description and estimate of the rocks in the vicinity of the Lake of the Woods,* Dr. Lawson assumed positions of such originality and boldness as to entitle his contributions to an important place in this sketch of opinions concerning the older rocks of America.

The schists in the vicinity of the Lake of the Woods had been noticed by Bigsby and the other early explorers. By Bell, they had been designated Huronian, from their resemblance, undoubtedly, to the schists misnamed Huronian, on the north and east of lake Superior.† Dr. G. M. Dawson first remarked the apparent volcanic origin of a large part of the "Huronian" ‡rocks.

Dr. Lawson is not satisfied to embrace all the older schists in the Huronian.§ He says:

"The schistose belt of the Lake of the Woods appears to me to differ from the typical Huronian of Sir William Logan both lithologically and in other respects. The typical Huronian of Logan is, from his description of it, essentially a quartzite series, in which the quartzites are true indurated sandstones. The schistose belt of the Lake of the Woods is not so characterized. Quartzites form an extremely small proportion of the rocks of the Lake of the Woods, and then they are only local developments in formations of mica schist and felsite schist. Bedded limestones are characteristic of Logan's typical series. On the Lake of the Woods, there are, so far as I have been able to determine, no bedded limestones, the nearest approach to them being small segregated bands of dolomite of the character of veinstones. These two differences alone are sufficient to throw doubt on the equivalence of the two series, if lithological character is to be regarded as an aid to geological classification. There are, however, other differences. The basal conglomerate of Logan's Huronian, on Lake Temiscamang,

*Report on the geology of the Lake of the Woods region, with special reference to the Keewatin (Huronian?) belt of the Archean Rocks. By Andrew C. Lawson, M. A. *Geological and Natural History survey of Canada.* Annual report (new series), Vol. i, 1885, Montreal, 1886.

†R. Bell, *Ann. Rep. Canada*, 1872-3, pp. 91-105; 1873-4, pp. 88-89. Also, and more in detail, 1880-2, pp. 12-15C.

‡G. M. Dawson, Geology and resources of the region in the vicinity of the forty-ninth parallel, 1875.

§The same dissent was expressed by the writer in a paper on "The Huronian System," presented to the *Amer. Assoc.*, New York, 1887; in one entitled, Systematic Results of a Field Study of the Archæan Rocks of the Northwest, *Proc. Amer. Assoc.*, Cleveland, 1888, p. 205-6; a paper on The Geological Position of the Ogishke Conglomerate, *Proc. Amer. Assoc.*, Toronto, 1889, pp. 234-5 and Two Systems confounded in the Huronian, *Amer. Geol.* iii, 212-14, March, 1889. See similar views embodied in a paper by N. H. and H. V. Winchell, *Proc. Amer. Assoc.* Toronto, 1889, pp. 235-242.

is described as holding pebbles and boulders, sometimes a foot in diameter, of the subjacent gneiss, from which they appear to be derived. The boulders display red orthoclase feldspar, translucent colorless quartz, green hornblende and brownish black mica arranged in parallel layers, which have a direction according to the attitude in which the boulders were accidentally inclosed. The rocks on the Lake of the Woods, which are in the following pages referred to as agglomerate schists, are not basal conglomerates. They are not at the base of the series included in the schistose belt, nor are they apparently composed of water-worn fragments, derived from the rocks upon which they rest.

"No fragments that can be referred to the underlying granitoid gneisses are found included in the agglomerate schists of the Lake of the Woods. All the facts connected with them point to a volcanic origin for these agglomerates, and the fragments are very frequently sharply angular, often with re-entering angles, although for the most part, they are elongated and lenticular in shape, as a result of pressure, and the paste in which they are imbedded does not differ from them materially, as a rule. In rare instances, they pass into a pebble or boulder-conglomerate, in which the pebbles are usually of a reddish felsitic material, and indicate the coëxistence of aqueous with volcanic deposition."

"The 'green slate rock' conglomerates at the mouth of the Doré river, lake Superior, described by Sir W. Logan, supposed by him to be equivalent to the rocks of his main Huronian area, appear to resemble the agglomerate schists of the Lake of the Woods. This Doré river area of 'green slate rocks,' is however geographically distinct, and appears to differ from the series in the typical Huronian region. The rocks are described as standing in a nearly vertical attitude, while those of the latter are comparatively flat. Neither are they associated with beds of quartzites or limestones to a material extent. Those differences, with the geographical separation, may, I believe, warrant us in considering the possibility of Logan having placed under one designation, two distinct series."

Other and good reasons are given for the opinions here set forth, but we must forbear to cite further.

"While thus the schists of the Lake of the Woods are older than the epoch of folding, and older than the granites which are intruded through them, Logan's typical Huronian has come into existence later than the time of folding of the gneiss, and possibly also, later than the main period of granitic irruption."

He refers to Irving's conclusions as supporting his own view. Citing Irving's full identification of the Animike series of Thunder bay with the typical Huronian, and his view of the apparent equivalence of each with the Marquette, Menominee and Penokee-Gogebic series, he asks:

"If then, the Animike and Huronian are identical, as Logan himself believed, as regards a portion, at least, of the Animike, what are the relations of the folded schists of the Lake of the Woods to that flat-lying series? Professor Irving has expressed the opinion 'that both the flat-lying Animike slates and the more northern, folded, iron-bearing schists are Huronian,' and gives a diagram to show the hypothetical identity of the folded and unfolded series on either side of the Mesabi range of granite and gneiss" (See anté, p. 203).

"The folded schists to the northwest, however, so far as the Lake of the Woods series teaches, are as different from the Animike as they are from the typical Huronian, and were probably folded with the gneisses, before the Animike rocks existed as such. The Animike series rests, apparently, on granite, along part of its western confines. The granite of the region appears, as is known to have been the case on the Lake of the Woods, and has been more recently determined to be true also for Rainy lake, to be of later origin than the folded schists*. Hence, in the superposition of the Animike rocks upon the granite, we have,again, a sharp distinction in geological time, between the Animike (Huronian?) and the folded schists to the west, as represented by the Lake of the Woods series."

Dr. Lawson thinks, in this view of the facts, "it is expedient that this series of rocks should receive a convenient name which shall be non-committal as to geological relations, and which may be used provisionally, till such time as those relations are established beyond question. The most appropriate name for the series that suggests itself to me is *Keewatin* [*Ke-way-tin*], the Indian name for Northwest, or the Northwest wind, which has been applied to the district within which the rocks occur."†

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*This view of the relative age of the granites and the schists has been more particularly argued by Dr. Lawson, in *Amer. Jour. Sci*, III, xxxiii, 473-480. Although the author speaks with confidence, the reader will not understand that the doctrine is established in the sense here conveyed.

†*Keewatin* as a Chippewayan term, has no authorized orthography. The sounds are represented in different European languages, according to the powers of the letters of those languages. It is doubtful whether the usage of the English language has a paramount right to impose a fixed form for universal acceptance on any Indian vocable, especially, when it is a term proposed for introduction into the universal language of geology. This diversity in the powers of letters in different languages, led Americanists long since, to the adoption of certain rules for the spelling of Indian names. The alphabet of Dr. George Gibbs, the recognized pioneer in American linguistics, was adopted by the Smithsonian Institution, and published with its sanction, in No. 160 of Smithsonian Miscellaneous Collections, 1866. The rules thus pro-

Coming to a geological description of the region, the author dwells upon the existence of great pre-glacial denudation; but in a later memoir, this subject is treated more at length.

To the gneissic and granitic rocks he ascribes an origin from molten material. He states that the non-orthoclastic constituents of the gneiss possess "a distinct flowed structure." The gneisses, he says, too, show a "passage into granites devoid of foliation" (p. 29). Of one of the granites he says:

"This rock, characteristically granitic in its nature, may be traced eastward over a comparatively bare country, and be seen to assume gradually, by transitions scarcely perceptible, a gneissic arrangement of the crystals, till at last, on the shores of Long lake, it presents a quite distinctly gneissic foliation" (p. 30).

A group of rocks of great importance but very obscure nature, is described as "agglomerates, tuffs and boulder conglomerates." The character which they present he considers due to "an extremely rapid process of deposition of intimately associated and often alternating, volcanic ejectamenta, (both flows and tuffs) and aqueous sedimentation, the material for which was derived partly from the volcanic products, and partly from the more silicious or acidic rocks which seem to have constituted the original floor of the trough" (p. 49).*

Further of the constitution of the agglomerates, he says:

"The included fragments of the agglomerates are nearly always more or less flattened or lens-shape, the greatest planes in the fragments being parallel with the planes of schistosity, which are in the great majority of cases observably identical with those of the bedding" (pp. 49-50).

The forms of the fragments are attributed to pressure. The agglomerates are said to pass, sometimes, into mica schists; and he says it is "not uncommon to find in these mica schists, a small proportion of feldspar, which gives them the character of finely laminated gneisses, in places."

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mulgated have been followed in the various publications of vocabularies made by the U. S. Department of Ethnology. (See, for instance, Contributions to North American Ethnology, vol. i, p. 249, 1877, and iii, p. 443, 1877). Under these rules, the vocable *Ke-way-tin* should be written *Ki-wé-tin*; as the vocable *Ke-we-naw* would be written *Ki-wi-na*. But should it be considered too late to adopt the Smithsonian orthography of these words, there certainly is no English reason for inserting duplicated "*e*", as in *Keewatin* and *Keweenaw* (why not *Keeweenaw?*). The least concession to the demands of simplicity and good orthographic reason, should prompt a user of the English language to write *Kewatin* and *Kewenaw*. For similar reasons, we should write *Animike*. not *Animikie* or *Animiké*; *Ke-ke-qua-bic*, not *Ka-ka-quà-bic*. Also, *Couchiching*, not *Coutchiching*.

*A similar view of the nature of the "diabasic schists" of Minnesota has been set forth by H. V. Winchell, in the *American Geologist*, iii, pp. 18-22. Jan. 1889.

Thus, since the gneiss graduates into granite, he discovers a mineralogical graduation between mica schist and granite.*

Particular attention is devoted to the relations of the gneisses with the associated schists. "The gneiss", he says, "in some places, holds large and small angular fragments of hornblende schist . . The planes of *lamination* of the schist and *foliation* of the gneiss are parallel, though there are *unmistakable* evidences that the contact is an igneous one, and that when there is a mixed alternation of gneiss and schist, the former has been *injected* within the latter [italics are the compiler's]. This mixture of gneiss and schist, with occasional short broken bands and fragments of schist included within the gneiss, occur at intervals along the shore of Darlington bay" (p. 64).

In another place, he speaks of "dykes and gneiss" cutting the schists, and presenting the appearance of "evenly intercalated beds" (p. 72). As we approach the great gneissic area, these intercalations become more frequent. At the junction between the gneiss and schists, there is "no sharply defined line of contact, but a transitional series of layers of alternate gneiss and schist" (p. 72).

He gives figures of such alternations, and says:

"The two rocks [are] apparently interbedded as a transitional alternation, but the gneiss [is] in reality intruded." In one place he enumerates sixteen alternations of gneiss and hornblende schist, "some of the gneissic beds being as thin as four inches, six inches, eight inches and one foot, with intervening schistic beds as low as eight, twelve and fifteen inches, all regular and bed-like in their characters;" "but their true nature," he says, "as injected sheets or dykes, is sufficiently revealed." This opinion seems to be rested on the facts that occasionally a bed of gneiss sends "irregular tongues" into the schists, or includes "fragments of the schist walls."†

The plutonic view is defended by the author with unmistakable ability, (p. 83, etc); but we have not the space for adequate citations. The Kewatin is held, with reserve, to be structurally conformable with the Laurentian; but at the same time, it is presumable that a real historic break separates them.

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*Nevertheless, so far as the writer can ascertain, he regards the Kewatin as embracing all the rocks down to the gneiss, where, for the reasons given, he discovers evidences of a very different sort of geologic agency.

†Similar relations of gneiss and contiguous schists are described in the *Fifteenth* and *Sixteenth Annual Reports* of Minnesota; but a different interpretation is put upon the gneissic beds. See also the writer's memoir in *Bull. Geog. Soc. Amer.*, pp. 357-394, Apr., 1890.

As to the general structure of the region, he says:

"The granitic intrusions of the area of the Lake of the Woods may be grouped under ten main centres of occurrence or distribution, with a number of bosses of minor importance, which appear to be independent of these."

These areas are regarded as so many outbursts through the overlying Kewatin and are therefore of later age. The granitic masses have a definite relation to the stratigraphical structure, and seem to lie in the lines of folding, and to have been affected by the same cause as produced the folding (pp. 100, 101).

Of the Kewatin series he enumerates and describes the following members:

"Granitoid rocks at either extreme.

"Hornblende schists with associated altered traps, the whole more or less chloritic.

"Agglomerate schists, varying in character from greenstones to micaceous or gneissic schists.

"Quartzose mica schist, sometimes gneissic, but lamination very even.

"Hydromicaceous and chloritic schists, and arenaceous slates.

"Granite (irruptive)."

1887. In continuation of the results of his studies in the Canadian Northwest, Dr. Lawson gave a preliminary account of the geology of the Rainy lake region.* This region geologically is a continuation of that of the Lake of the Woods. He here brings out more expressly his belief that the granitic and gneissic rocks are younger in respect to the conditions in which we know them, than are the crystalline and semi-crystalline schists. He says truly:

"We do not yet know their original condition prior to the fusion from which they solidified into granites, syenites and gneisses. They may have been sedimentary; they may have been the original crust of the earth. But whatever may have been that original condition, the evidence is clear on this point, viz: that the fusion and solidification whereby they were brought into their present condition as firm crystalline rocks, took place at a period subsequent to the existence, in a hard, brittle condition, of the stratiform, and often very distinctly clastic, rocks which occupy the higher place in the column. Therefore, as rocks, the members of this fundamental system are of younger age than those of the nearest overlying formations."

But he draws the line of distinction between igneous and sedi-

**Amer. Jour. Sci.*, III, xxxiii, 473-480, June, 1887.

mentary rocks at the crystalline schists. He includes here certain fine-grained, bedded rocks for which he proposes the term *"granulite gneiss."** The schists generally known as crystalline schists, occupying a position between the gneisses and the semi-crystalline schists, are here separated from the latter, and receive the name, "Coutchiching series."†

He says of them:

"They are very sharply and distinctly marked off from the lower granites and gneisses of the Laurentian. The geological contact between the Coutchiching series and the Laurentian is one of neither conformity nor unconformity. The break is of an entirely different order, and the contact is eminently that of an igneous injection or intrusion of the lower through the upper rocks" (p. 477),

The overlying [Kewatin] schists are "of entirely different character." The rocks are for the greater part "of volcanic origin" Though structurally conformable with the Couchiching series, the appearance of parallelism may be the result of folding and pressure. The diverse character of the rocks of the two series is proof of a profound alteration in the conditions of rock formation, which implies a geological break.

Regarding the systems in order of superposition, he arranges them thus:

Kewenawan (Nipigon).
Huronian (Animike).
Kewatin.
Couchiching.
Laurentian.

But regarding them in the order of age, they would stand thus:

Kewenawan (Nipigon).
Huronian (Animike).
  Diabase dykes and gabbro,
  Granite, post-Laurentian.
Laurentian.
Kewatin.
Couchiching

1888. Dr. Lawson's final report on the geology of Rainy lake region appeared in 1888.‡ This thoroughly scientific memoir, in the discussion of doctrines, is devoted rather to the strengthening

*This convenient and appropriate term has been used many years by the present writer. This, as also "granulite schist," are given in his "Geological Studies," pp 51 74, 76, etc. 1886.

†Better *Couchiching,* for reasons stated above.

‡*Geological and Natural History Survey of Canada.* Annual Report (New Series), vol iii, Part I, pp. 182, with a map.

of positions previously assumed than to the elimination of new views, and thus, in spite of its value, does not seem to demand more than the citation of a few passages. Among the facts however, which possess greatest interest, are some occurrences of a conglomerate which, as nearly as may be judged, is an extension of the Ogishke conglomerate of Minnesota.

"On the shores of Rat-Root bay, the basal beds of the Keewatin are pebble-conglomerates, of which the paste is a green schist, and the pebbles mostly water-worn, rounded or oval pieces of vitreous or saccharoidal quartz. Some of the pebbles are feldspathic, and when so, are occasionally foliated. On the south shore of the bay, boulders of granite are observed to form part of the conglomerate, one boulder being at least eighteen inches in diameter, and of a roughly rounded shape" (pp. 38, 82, 105).

Again on Grassy lake, the basal beds of the Kewatin "are fissile, soft, green-chloritic and hornblendic schists, the detrital origin of which is established by the fact that on the north side of the lake, they constitute the paste of a pebble-and-boulder-conglomerate" (pp. 55, 82). This conglomerate is much more voluminous on the north side of Shoal lake.

Among the soft fissile, glossy gray schists of the Kewatin series at the west end of Schist lake, there are several beds of conglomerate, the pebbles of which are mostly quartz rock, and the matrix a soft, more or less calcareous, decomposed schist, stained yellowish with oxide of iron.

He notes the parallelism of the two series and says again, this affords but little evidence of original conformity; and relies upon the abrupt lithological contrast for evidence of a historical break. The conglomerate he regards as a *basal** conglomerate "in which the pebbles have very probably been derived from the underlying formation" (pp. 56, 105).

He notes, what has also been observed in Minnesota, that the series of crystalline schists is quite inconstant in its occurrence. Sometimes the Kewatin rests on the gneiss, and then the basal member is likely to be hornblende schist. But this schist is apt to be wanting when the Kewatin rests on mica schist (p. 38).

Of the hornblende schists he says:

"There is much presumptive evidence in favor of the view that they are partly altered, massive rocks, and partly altered, volcanic ash-beds (pyroclastic), but little or none, that they are the alteration products of clays or other forms of detrital matter."

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*This position of the Ogishke Conglomerate of Minnesota has seemed to the writer clearly pointed out by the facts observed. See *Sixteenth Ann. Rep.* Minn. pp. 344-350; 359-360.

The changes undergone have been so profound that the original character has been destroyed, and a new rock of different constituent minerals has crystallized *in situ*. Pressure and crushing may have been potent in the destruction of the original structure; but in the later history, chemical or metamorphic forces have been chiefly active, and have obliterated all the traces of crushing (p. 73).

Of the soft, fissile, green schists he says:

"These are schists closely resembling the paste of some of the conglomerates. They are usually distinctly bedded. Their clastic origin can scarcely be doubted, though, as in the paste of some of the conglomerates, their association with bedded traps and their mineralogical analogy with the altered phases of those traps, renders it extremely probable they were never ordinary clays, but were originally fine-grained, volcanic ash-beds, the constituent minerals of which have suffered alteration and decomposition along the same lines as those observable in the traps" (p. 82).

He finds few serpentines. Their relations to the rocks adjoining them are ill-defined. They appear to be the alteration products of igneous masses which have the same geological age as the traps and other volcanic rocks of the Kewatin series; and although their common boss-like character suggests that they are intrusive through the Kewatin rocks, such intrusion has probably taken place coëval with the bedded formations, volcanic and sedimentary, of the Kewatin (p. 97).

In reference to the relations of the Couchiching series to the Kewatin and Laurentian, he remarks:

"Without being able to conclusively prove it, there appears to be much presumptive evidence in the facts cited, to show that the present eminently crystalline state of the Coutchiching series is the result of the metamorphism of strata which were originally in large part, ordinary quartzose sediment, although part may possibly have been acid volcanic rocks, such as quartz-porphyries or felsites. In many parts of the series garnets abound, and if the rocks were carefully examined, other metamorphic minerals would doubtless be found. That percolating silicious solutions were active agencies in effecting the metamorphism of these strata, is proved by the fact that in many places, particularly on the north side of Saginaw bay and east of Brulé narrows, the partings between the beds have served as fissures for the deposition of vein-quartz. This vein-quartz is very abundant in lenses or lens-like sheets, and is clearly a secondary product in the rock. The same watery solutions which desposited the quartz in these lenses, in the more open portions of the formation, must have saturated the rock throughout, and given rise, probably, to much of the quartz and feldspar in it. Only in one instance has hornblende been observed throughout the whole series. There are no intercalations of basic volcanic rocks, and none that can now be distinctly recognized as acid volcanic rocks. There are no limestones or dolomites in the series, nor have any conglomerates been observed." (p. 105.)

The subject of inclusions in the Laurentian gneiss is very particularly treated. These gneisses, both of the granite and the syenite type, frequently consitute a matrix in which angular fragments of schists are inclosed. These are most abundant in the vicinity of the lines of junction with the overlying schists. The included fragments may belong either to the Couchiching or Kewatin series. Along the zone of contact, apophyses or dykes from the gneiss penetrate the contiguous sheets. These facts are thought to prove that the inclusions are simply detached portions of the overlying formations "which in a firm and brittle condition, have become immersed in the underlying viscid magma, which subsequently crystallized out as the Laurentian gneiss and granite It seems probable, too, that such shattering and detachment of fragments took place at the last stages of crumpling of the crust in this region. . . After the solidification of the Laurentian gneisses, there was no farther very violent deformation of the crust, for the Laurentian rocks appear to have resulted from the fusion not simply of the floor upon which the Coutchiching and Kewatin rock first rested—what ever such floor may have been*—but also with it of portions of those series" (pp. 130, 131).†

1890. Early this year, Dr. Lawson published a thoughtful and important memoir on the internal relations and taxonomy of the Archæan of Canada.‡ He discusses, first, the separability of the Archæan into two divisions, which, with subdivisions, would present the following scheme:

*The recognition of the necessity of a "floor" on which the marine sediments could have rested, is a tacit admission of the existence of a geological formation older than that formed from the sediments. To say that we know nothing of that solid floor except as an inference, is the same as we must say about the former fused or plastic condition of the granites and gneisses. The indications of such plasticity afford no stronger basis for the inference than the indisputable necessity of a solid non-igneous sea-bottom to support the waters of a sediment-laden ocean. We have, in reason, in both cases, satisfactory ground for a conclusion, and in both cases, proof from observation is precluded. In fact, the concluslon that molten masses of granite emerged through or into beds of strata already existing, possesses the same kind of support as the conclusion that a solid foundation earlier existed for the penetrated strata to accumulate upon. It is, in short, demonstrable that the schists have no claim to be reckoned first in the order of time.

†Phenomena of the class here described have also been fully detailed, with many illustrations, from the contigous territory of northern Minnesota. See *Fifteenth* and *Sixteenth Annual Reports, Geol. Surv. Minn.*, 1886, 1887.

‡*Bulletin of the Geological Society of America.* pp. 175-194, March 20.

ARCHÆAN.
  Ontarian. [Now first proposed.]
    Kewenian.* [Nipigon.]
    Huronian. [Animike.]
    Kewatin.* [Often confounded with Huronian]
    Couchiching.* [Vermilion of N. H. Winchell.]
  Laurentian.

In presenting a petrographical description of the members of the Ontarian division he says of the hornblende schists:

"The field evidence points to their derivation from basic volcanic rocks," and cites examples from Norway and Scotland tending to prove "the derivation of the bulk of the hornblende schists from normal volcanic massive rocks, which were originally bedded with other stratified rocks, either as flows or as injected sills. Other hornblende schists are probably derived from an analogous alteration of tuffs of basic volcanic rocks" (p. 179).

As to the extent of the influence of metamorphism in the Ontarian system, Dr. Lawson offers reflections which narrow the gap between him and the metamorphic school. He says:

"In deference to these [plutonists] and other anti-metamorphic schools of thought, in which for the most part, theory seems to crowd out fact, it becomes necessary, with the accumulation of evidence of recent years, to point out the great additional strength acquired by the theory of metamorphism as applied to the Archæan by the recognition of the volcanic origin of much of the material upon which metamorphic agencies have operated, and by the limitation of its application to the upper division [Ontarian] of the Archæan; the rocks of the lower division, or Laurentian, being susceptible of an entirely different explanation. The lack of discrimination between the essentially different characters of the upper and lower Archæan, and the lumping of the whole complex together as having necessarily the same origin and development has been the great mistake alike of the metamorphic and the extreme plutonic schools. Just as the metamorphic theory, properly limited, affords the explanation of the development of the rocks of

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*Kewenian is not named in this connection, but in previous documents it is put in the position here indicated.

Although this slightly simplified orthography of three of these divisions is here used by the writer, the terms are considered the same as those employed by Dr. Lawson.

In writing of the Couchiching series, for which the name "Vermilion series" was employed by N. H. Winchell about the same time as proposed by Dr. Lawson, he takes occasion to express regrets that the present writer had used "Vermilion series" and "Vermilion system" "in a much more comprehensive, but still undefined sense." It is proper to say that those expressions were not intended as taxonomic in value, but simply as geographical, referring to the whole assemblage of rocks about Vermilion lake.

the upper Archæan from normal formations, so by a similar limitation of the plutonic theory, and the introduction of some modifying considerations, we will find in the latter, a rational and consistent explanation of the origin of the rocks of the Laurentian" (p. 181).

In another memoir, Dr. Lawson has recorded* important observations on the pre-Palæozoic surface of the Archæan terranes of Canada. The surface known as *roches moutonnées*, generally attributed to the action exerted during the last glaciation, is seen to have existed when the Palæozoic sediments were laid down—formations of whatever age adapting their under surfaces to the bossy surface of the Archæan.

Another announcement possesses similar interest. Vestiges of Palæozoic strata are now known in so many districts resting in the protected depressions of the Archæan, that it appears probable that a large part of the Archæan surface was once covered by a blanket of fossiliferous rocks. In this view, the region which we call the Archæan nucleus of the continent was not visibly such until after a vast amount of denudation; though of course, it really existed as a grand swell in the fundamental structure of North America. A further inference from such a fact is the certainty that the material of the Palæozoic sediments was derived from some source now lost to view.

It becomes necessary to bring to a close our citations from the views of American workers on the nature and history of the older rocks. Though the undertaking has produced more voluminous results than were anticipated, there still remains a large body of valuable opinions, to which justice demands, probably, that some reference be made—opinions both of those who have been quoted, and opinions of others who, thus far, have been but incidentally mentioned. Regretting the necessity for these omissions, the compiler hopes, nevertheless, that what has been presented, may prove useful to many students in this difficult field of inquiry.

ERRATA.

Page 77—For "Bucoides" read Fucoides.
Page 83—For "It is intended" read It is not intended.
Page 108—After "Georgia trilobites" insert to.
Page 113—Dele "[4]" and five lines below substitute [4] for [5].
Page 126—Last line for x read plus.
Page 207—For "resents the following" read presents the following.

* *Bull. Geol. Soc. Amer.* 163-174, March 12, 1890.

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VIII.

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