Journal of the Minnesota Academy of Science

Volume 5 | Number 1 Article 4

1911

The Iron Ore Ranges Of Minnesota, And Their Differences

N. H. Winchell

THE IRON ORE RANGES OF MINNESOTA, AND THEIR DIFFERENCES.

N. H. Winchell, late State Geologist of Minnesota.*

1. There are two great iron-bearing formations.

When in the forties of the last century, iron ore was discovered at Marquette, in the state of Michigan, nothing was known of the relations it might have with the rocks in which it occurred, nor of the rocks with each other. Neither the state geologist, Dr. Douglass Houghton, nor the United States geologists, Foster and Whitney, paid much attention to the structural geology of the region. Indeed, it was one of the tenets of the famous report of Foster and Whitney that the "Azoic" was not susceptible of classification, nor of subdivision, so far as it appeared on the south side of lake Superior, and this idea was not dispelled until the region was examined by the later state surveys of Michigan and Wisconsin, and by the geologists of the United States Geological Survey. Several of the field geologists passed over the critical stratigraphic exposures without comprehending their significance. Dr. Rominger, of the Michigan survey, called attention to some non-conformities at Marquette which would have led him to discover the duplicate nature of the iron-bearing rocks if he had sufficiently appreciated their significance. Foster and Whitney in making a survey of the iron district of Michigan, also Irving for the later United States Geological Survey, and Brooks for the Michigan State Survey, believed that not only the rocks were in one great "azoic" series, but that the iron ore was confined to one horizon. If they saw conglomerates, great conglomerates such as are now universally recognized as basal beds which indicate non-conformities, (and some of them did see them) they either believed them to be local breccias caused by igneous outbreaks of granite or dioryte, or put them along with the ore into the same formation.

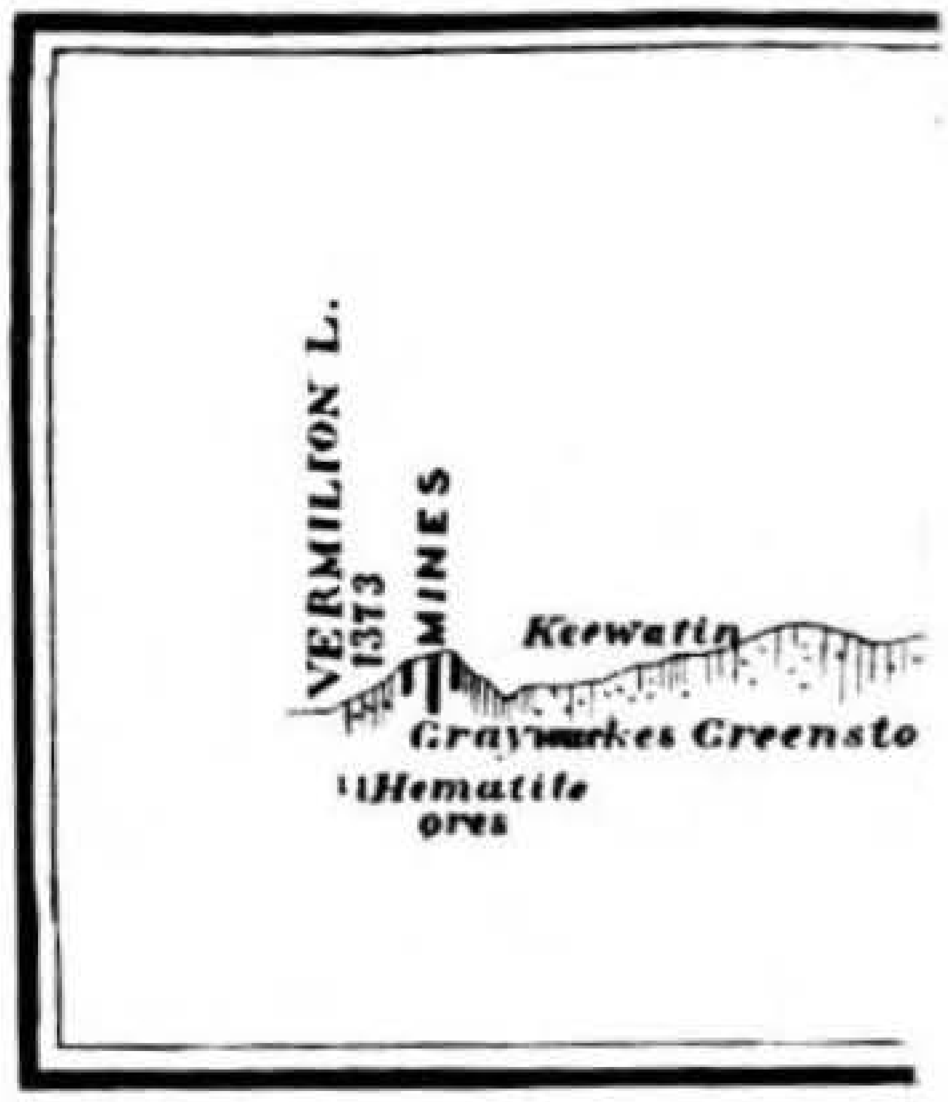
It was only after some examination of the geology of northeastern Minnesota by the members of the Minnesota Geological Survey that it was learned that, at least so far as concerns the state of Minnesota, the iron ores are not all in the same formation. We found that the rocks that contain the ore at Soudan are much older than those that carry the Mesabi ore. We found that the Mesabi rocks, which are the younger, run in a diverging course, from the line of strike of the rocks that carry the Vermilion ore. Spurred by this discovery, we organized a small party and visited Marquette, where the greatest development had been made. We also examined the Penokee-Gogebic rocks, in Wisconsin, and without going now into the details so far as those iron regions are concerned, we con-

*The paper was given February 22, 1911, as a public address at Aitkin, and subsequently at the May meeting of the Academy of Science. The figures were shown on a screen by stereopticon.

cluded, not only that on the south side of lake Superior there were two different ore horizons, but that at Marquette they were both to be seen easily in the mines that were being exploited. The first formal announcement of this important generalization* which ever was published was made in the sixteenth annual report, 1887, of the Minnesota survey, pp. 43-47. It was amplified in the seventeenth, 1888, pp. 43-45, and, when the priority of our discovery was questioned by some of the Wisconsin geologists, it was defended in the twenty-first annual report, 1892, pp. 87-99. It was very soon recognized as an important fundamental datum in all research work in the geology of the Lake Superior region. It is the starting point in all intelligent exploration, for it is very evident that unless the exploring geologist knows how the strata run, and what their position with respect to the ore which he is to search for, he is very liable to expend a large sum of money by working in the dark.

Fig. 1.—Location of the Iron ranges of Minnesota.

*The initial dissent from the idea of the "Huronian" age of all the ores of the Lake Superior region was published in the thirteenth report of the Minnesota survey, pp. 24-37, 1884.


VERMILION L.
1373
MINES
Keewatin
Graywackes Greensto
Hematite
ores

2. **Differences of Geographic Location.**

In order that this great difference in the stratigraphic relations of the great iron-bearing formations may be fairly understood I will illustrate it by a few lantern views.

(1) Northern Minnesota, showing the areas of the Keweenawan and Taconic, and of the Archaean; also the geographic positions of the Vermilion and Mesabi iron ranges. This view is taken from the Collections of the Minnesota Historical Society, Vol. VIII, paper read January 21, 1895. The rocks of the Vermilion range extend westwardly a great distance. The indication on the map shows only where they have been seen, and especially where they have been known to carry more or less ore like that at Soudan. These rocks are not simple, but complex, and yet they have some general characters in all areas in which they are uniform, and by which they can always be distinguished from the rocks of the Mesabi range. For our present purposes these are the only formations which it is necessary to consider—two great non-conformable formations separated by what has been called by Lawson "the great eparchaean interval."

(2) A section of the rocks extending from Soudan near Vermilion lake, southward under lake Superior to the Penokee range at Penokee gap, showing the dip of the different formations. Here are the Archean rocks at Tower, or Soudan, standing vertical, disappearing under the rocks of the Mesabi range and reappearing on the south side of the lake still maintaining their vertical attitude It is these rocks that hold the ores of the Vermilion range. Overlying these vertical strata are the gently dipping strata that carry the Mesabi ores, and above them are the trap rocks, gabbro, sandstones and shales that compose the great Keweenawan formation which on Keweenaw point are famed for the metallic copper which they have furnished. The Mesabi rocks and the copper-bearing rocks agree essentially in dip, and are closely related in age. This diagram is taken from the sixth bulletin of the Minnesota survey, "The Iron Ores of Minnesota," published before the great working of the Mesabi range and cotemporary with the first discovery of merchantable ore on that range. This non-conformity extends, so far as has been observed, throughout the whole Lake Superior region, all over Canada and New York and New England. This remarkable fact has great significance, nothing less than the date of separation between two great world epochs.

3. **Structure of the Vermilion Range Rocks.**

If we inquire now how these formations can be distinguished, we enter upon the actual problems that confront the geologist, both in the field and in the laboratory. It is not possible to give the detailed differences nor the steps by which these differences have been determined. Suffice it to state that the main result was reached after long field examination and mapping, and after minute examination of the mineralogic characters. Before arriving at that stage in the research where we were qualified to give reliably the conclusions of our labor, we had spent 21 years on the investigation, and had minutely examined 1000 microscopic thin sections of rocks gathered in the course of the survey. What I shall give you will be the merest skeleton, and will embrace only some of the most tangible features. If you wish for more detail you may examine the reports of the Minnesota survey, especially volumes four and five of the final report.

I have already stated that the rocks of the two series are distinguished by their different geographic area and by their contrasting stratigraphic attitude. But they are also different in their composition and internal structure.

I will show you a few lantern slides that portray the internal structural relations, first, of the rocks of the Vermilion iron range, and of their associated strata. The Vermilion ore is in the bottom of the Archean, the oldest rocks known in the state, and in the entire Lake Superior region. If they were horizontal, as they must have been originally, they have been compressed horizontally and folded upon themselves, backward and forward, so as to be repeated perhaps several times in any section that might be observed in traveling across the folds.

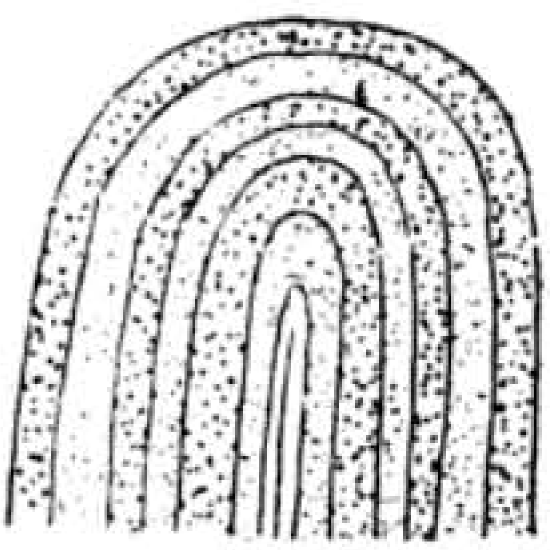


Fig. 3.—Folded Archean Strata.

(3) This slide exhibits the top of a fold actually observed in Minnesota, near Burntside lake. If the top of this lot of folded strata were to be cut off horizontally, as we know all the Archean strata have been by the waste of time, and especially by the abrasion of the Glacial epoch, there would be a series of beds standing vertical, running parallel in belts of outcrop, differing from each other in orderly variations from the center of the fold in opposite directions. It is only where the rocks are bare over large areas that the identity of strata on opposite sides of such a fold can be traced out and proven, and very seldom has such a succession been proved.

In this folding and squeezing process changes were wrought in the mineralogical composition of the strata. Heat, derived partly from the friction and partly from the interior of the earth, produced chemical transformations, and new minerals resulted from such a metamorphism, and the sediments became crystalline, sometimes producing mica and hornblende schists and sometimes gneiss; and, if, in such plastic condition, these recrystalized materials were thrust by pressure into any of the cracks, or were extruded at the surface, they became granites of the various degrees of acidity, or sheets of lava. They formed dikes and bosses and all kinds of irregular masses. If they cooled and solidified without being moved from their places they formed gneiss, which is for the most part simply a sedimentary rock re-crystallized where it was first deposited.

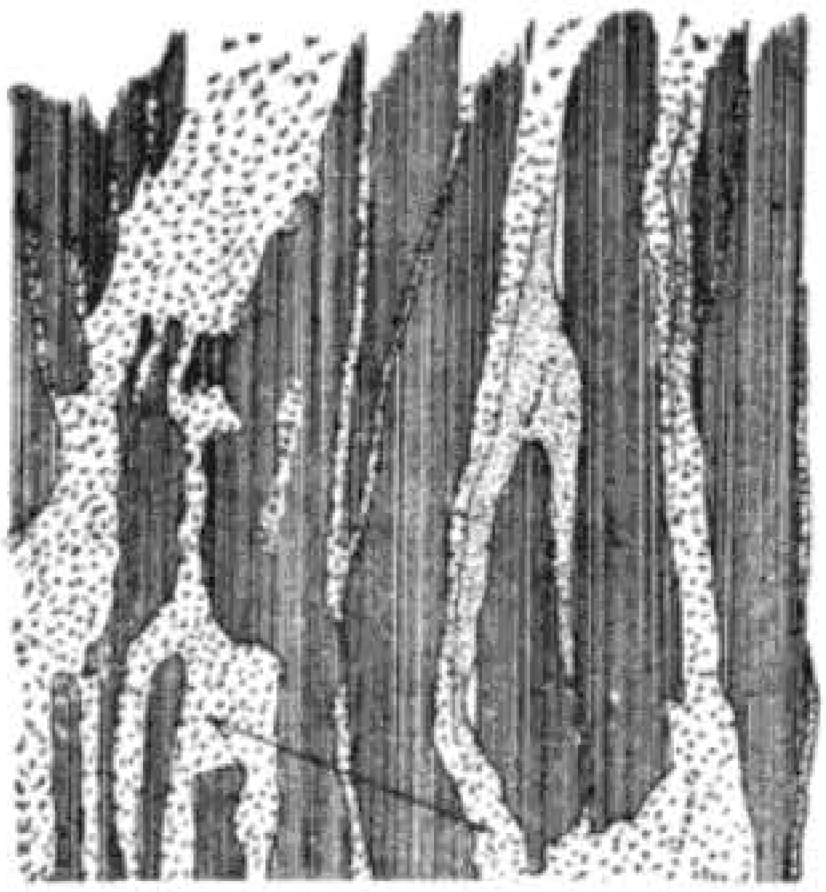


Fig. 4.—Mica schist intruded by granite.

(4) The next slide shows some of these recrystallized sedimentary rocks. The original sediments, represented now by the mica schist, were penetrated and crossed by granite in diagonal intrusions and in parallel laminations. This granite is not supposed to have come from a deep-seated source, but from some nearby locality where the original rocks were fused, or at least plastic so as to enter any cracks that were formed in the adjacent sediments.

This vertical attitude of the strata is seen at all the open mines in the Vermilion range. Here however the original rock was not an acid sedimentary one, but a basic igneous one. Outside of the mines, at short distances to the north or south, however, this igneous, basic, green rock is replaced by acid sediments. It is a very significant and remarkable fact that the ore of the Vermilion iron range is in a basic igneous formation, one which has been called "Kawishiwin", and that in some cases it is in somewhat regular alternation with layers of such igneous rock. We will not dwell here on the importance of that fact, but will pass at once to some slides that show that structure.

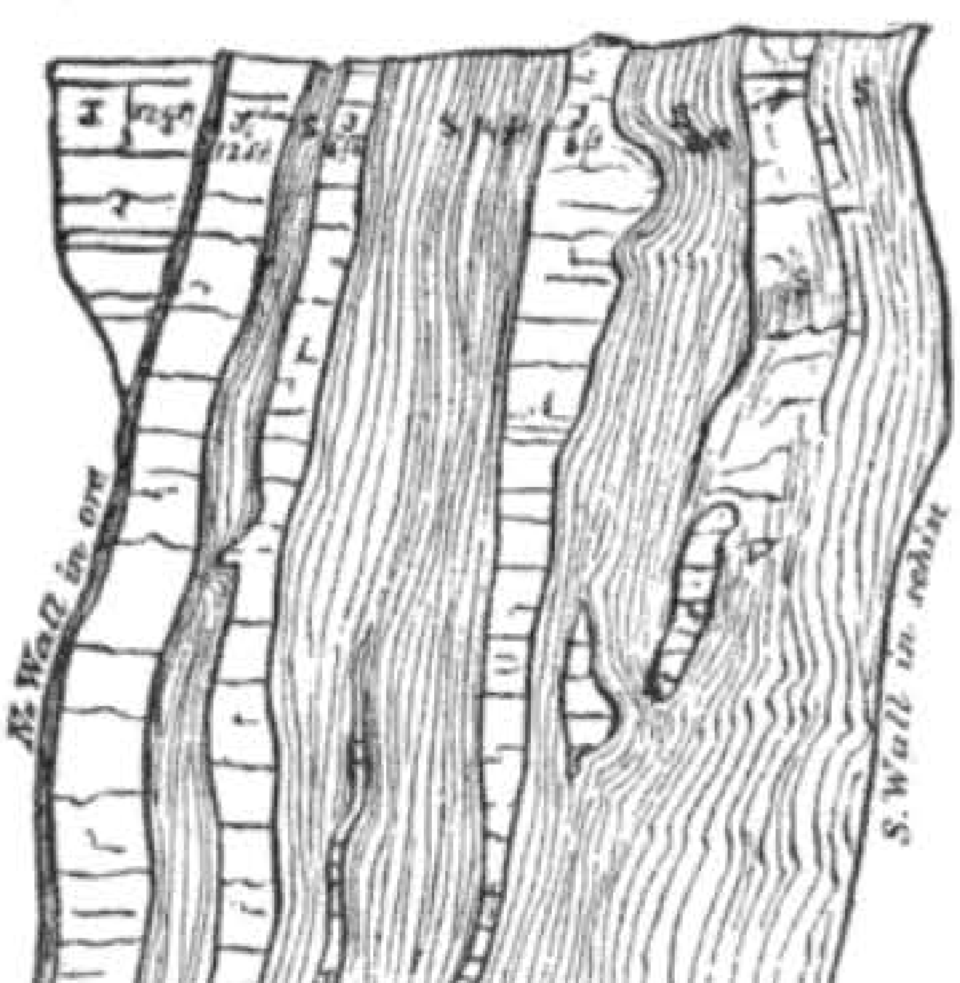


Fig. 5.—Jaspilyte and Green Schist.

(5) This slide shows the ore, which is also called jaspilyte when it is of low grade and distinctly banded by silica, alternating with green schist, both standing vertical.

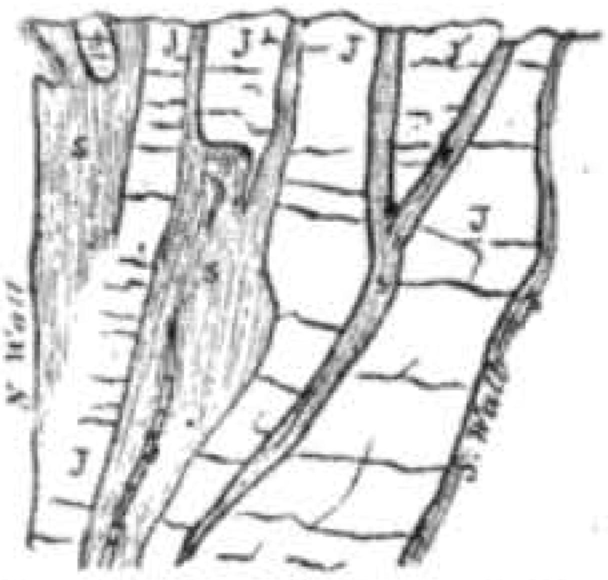


Fig. 6.—Jaspilyte and Green Schist.

Fig. 7.—Ore and Green Schist

(6) This also shows the same structure. These were both seen in the mines at Soudan, in the early stages of the mining at that place, and could have been repeated many times at all the original openings.

(7) This is another illustration of the same fact. In short, in all the mines, whether at Soudan or at Ely, the grand structure is the same. There are minor irregularities due to later fracturing and displacement, but these can easily be seen to be local and of later date than the orignal stratification.

One singular structure was observed at the "Stone mine" at Soudan which was appealed to by Dr. M. E. Wadsworth to show that the jaspilyte is of igneous origin, viz., a so-called "dike" was seen to diverge from the main jaspilyte mass, and to cut somewhat diagonally across the green country rock. The place where this jaspilyte

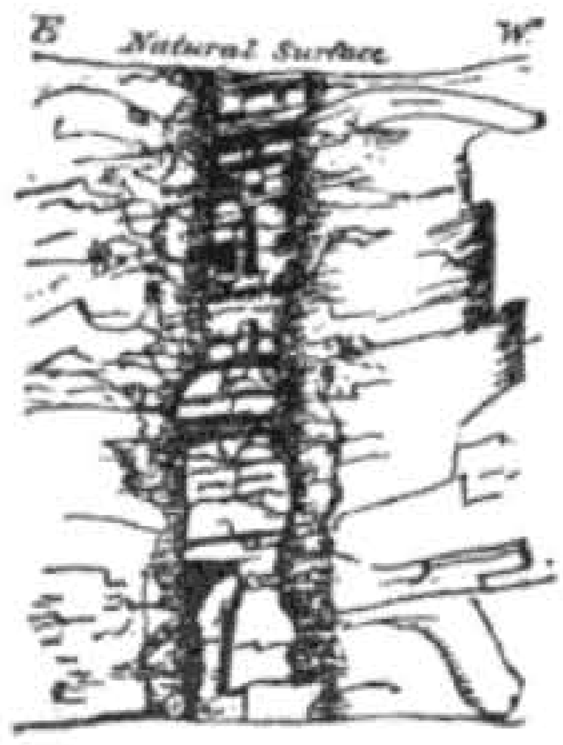


Fig. 8—So-Called Dike of Jaspilyte

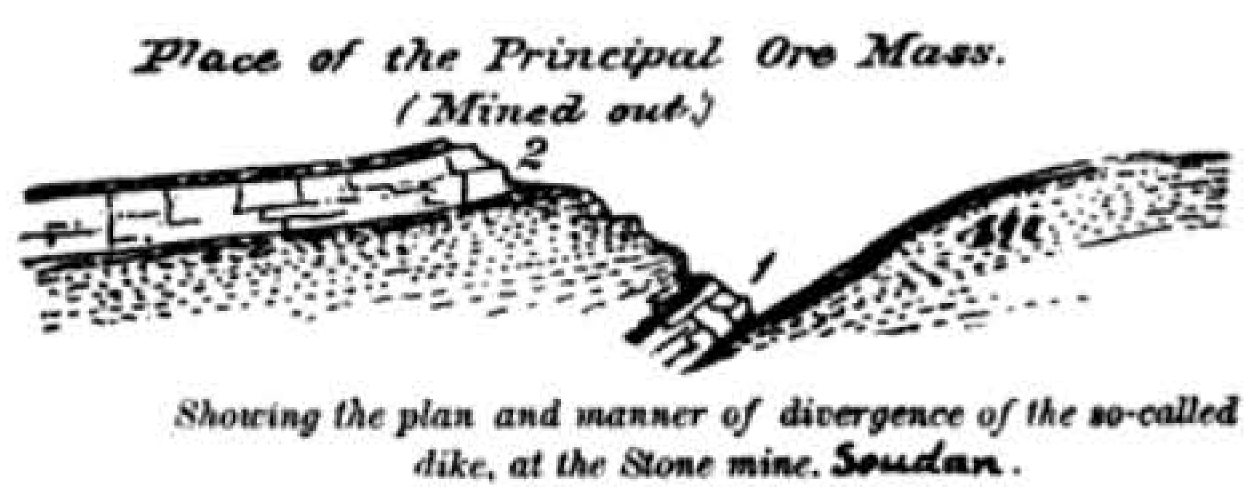


Fig. 9—Ground Plan of the So-called Dike.

spur, which consisted largely of good hematite ore, entered the wall of the mine as it stood vertical, is shown by this slide. (Fig. 8).

(8) Which was a drawing made on the spot. As this spur, in its course, rose to the natural surface, its manner of divergence was visible and the surface plan of the divergence was evident and was also sketched as shown by the next slide. (Fig. 9).

(9) In the light of what we know now it is apparent that this diverging spur of jaspilyte is only the commencement of one of those separate ore masses which spring up (in section) in the midst

of the schist nonconformable with the schists in a manner already illustrated. Several others are illustrated by Dr. Wadsworth at Marquette. (Notes on the Geology of the Iron and Copper Districts of Lake Superior. Mus, Comp. Zool., Geol. Ser., Vol. 1, 1880.)

What is Jaspilyte?

Now let us go a little more into detail.

Anyone who has read the descriptions published in the Minnesota reports can not have failed to encounter the word "jaspilyte" a great many times. It will be well to dwell a few minutes on the question, What is jaspilyte? The view here seen, No. 10.

(10) Shows a characteristic exposure of this rock. It is the rock which first attracted the attention of the early explorers who were seeking iron ore. It forms the summits of the great ridges seen at Soudan and elsewhere. It is not always iron ore, but it contains in nearly all cases a considerable proportion of hematite ore. Indeed it becomes the iron ore of the Vermilion range by an increase in the percentage of hematite. The beautiful banding seen is formed by alternations of iron ore and silica. These bands are about an inch in width, but sometimes less than half an inch, or more than six inches. The silica is usually colored red, or purple, or almost black, with the presence of iron, or at least of iron ore, but sometimes is white. These alternating brightly colored bands form a handsome surface, and their beauty is very often enhanced by the manner in which they are bent and apparently twisted together.

As there are three conditions in which this jaspilyte is found in these knobs I wish to call your attention to a feature seen in this slide. Along the lower side you see a change in the direction and regularity of the bands. There is also a change in their composition. Some of the bands here consist of green chloritic material, and as this increases in receding from the main jaspilyte mass, so it grades into a green schist, and this schist is not easily distinguished from the green schist which, all about here, plays a great part in the composition of the country rock. This stratigraphic graduation from the alternating bands of jaspilyte into the green schist cannot always be seen at the contacts of the contorted jaspilyte upon the schist. But as it occurs in several places plainly, it shows identity of age and method of formation—at least for those parts that are thus interstratified. But care must be taken here to not include the entire jaspilyte mass in this inference, for it is just as plain that, even in the majority of cases the jaspilyte and the green schist had different origins although about cotemporary. The contorted bands of jaspilyte have frequently an abrupt and nonconformable contact on the green schist, or on the green stone in which it lies. This nonconformity is less evident in this view, but can be observed at the plane where the contortions cease and where the green element in the stratification begins to appear.* The only inference to be drawn from this is: that from some primary source, and from a greenstone as a source, contemporaneously two sorts of sediment were brought into the ocean and laid out in successive strata, according to the action of the ocean's currents. It can be shown satisfactorily that the silica of the jaspilyte in its primary masses was derived from chemical deposition and as the silica in these interstratified bands cannot be distinguished from that in the primary mass, it is necessary to allow that the silica in the inter

* On the plate this plane is indicated by the two white stars.

Fig. 10.—Characteristic Surface of Jaspilyte...Soudan.

stratified jaspilyte was also derived from chemical deposition. Whatever may have been the physical conditions that obtained when the silica of the primary masses was deposited it is plain that that which forms layers interstratified with fragmental material, was chemically precipitated from solution in the bottom of the ocean in which the sediments were accumulated. These fragmental sediments are not always simply green schist, but also may be darker and more slaty strata, and may even grade into various kinds of detrital rocks, but in all such cases the chemically precipitated silica is evidently present—though not always as distinct homogeneous bands. It is then apt to be disseminated as a binding material amongst the fragmental sediments, forming horn slates, fine graywackes, chert, and different very siliceous fine schists. We have then here two forms of jaspilyte, viz: that which is interstratified with green schist conformably, and that which is in masses nonconformable with the green schist, or with the greenstone of the region.

There is a third sort, and this third sort is usually found in immediate contiguity with the other sorts. It should, first, here be stated that the Archean is divided into two main parts, the Lower Keewatin and the Upper Keewatin, and that a great conglomerate is at the base of the Upper Keewatin. This great conglomerate is composed of debris, both coarse and fine, derived from the Lower Keewatin. The jaspilytes already described are in the Lower Keewatin, but the third sort is in the Upper Keewatin, and is found in connection with this great basal conglomerate. Indeed, it is simply a débris derived from the other two sorts, and it is stratified as fragmental sediment in the midst of other sediments, evidently in the waters of a widespread ocean. It is not pure and clean. It does not form bands of the kind seen in the Lower Keewatin, but its pieces mingle in sedimentary strata with other pieces so as to make grits, graywackes and quartzytes, and to grade in fineness so as to be integral parts of some schists and slates. Considering only the quartz, each individual unit of the sediment is not a simple quartz grain but a grain of jaspilyte consisting perhaps of many microscopic quartzes. While the other two sorts may be called primary jaspilyte, this sort is certainly a secondary jaspilyte. This secondary jaspilyte is seen in this view.

(11) Secondary jaspilyte. It so happens that at the place where this photograph was taken the rock has been pressed and sheared so that all the parts are elongated in the same direction. On the south slope of the west range of the two jaspilyte ridges at Tower this secondary form of jaspilyte is seen well exposed all along the southern side of the hill; and some of the detached masses are very large. They form a part of the great conglomerate which constitutes the base of the Upper Keewatin.

5. **The rocks of the Vermilion range.**

After this particular description of the jaspilyte of the Vermilion range, it is necessary only to glance at the rocks themselves that constitute the formation in which the ore is embraced.

FIRST, and most conspicuous and important is a great basic greenstone, which shows all the characters of an old igneous rock. It is not a debris. It is not stratified, but massive. It extends northeasterly to near Gunflint lake, where it seems to sink away and granite takes its place. It forms the highest hills of the Giant's range of mountains, south of Ogishke Muncie lake.

SECONDLY, there is a large amount of stratified green schist,

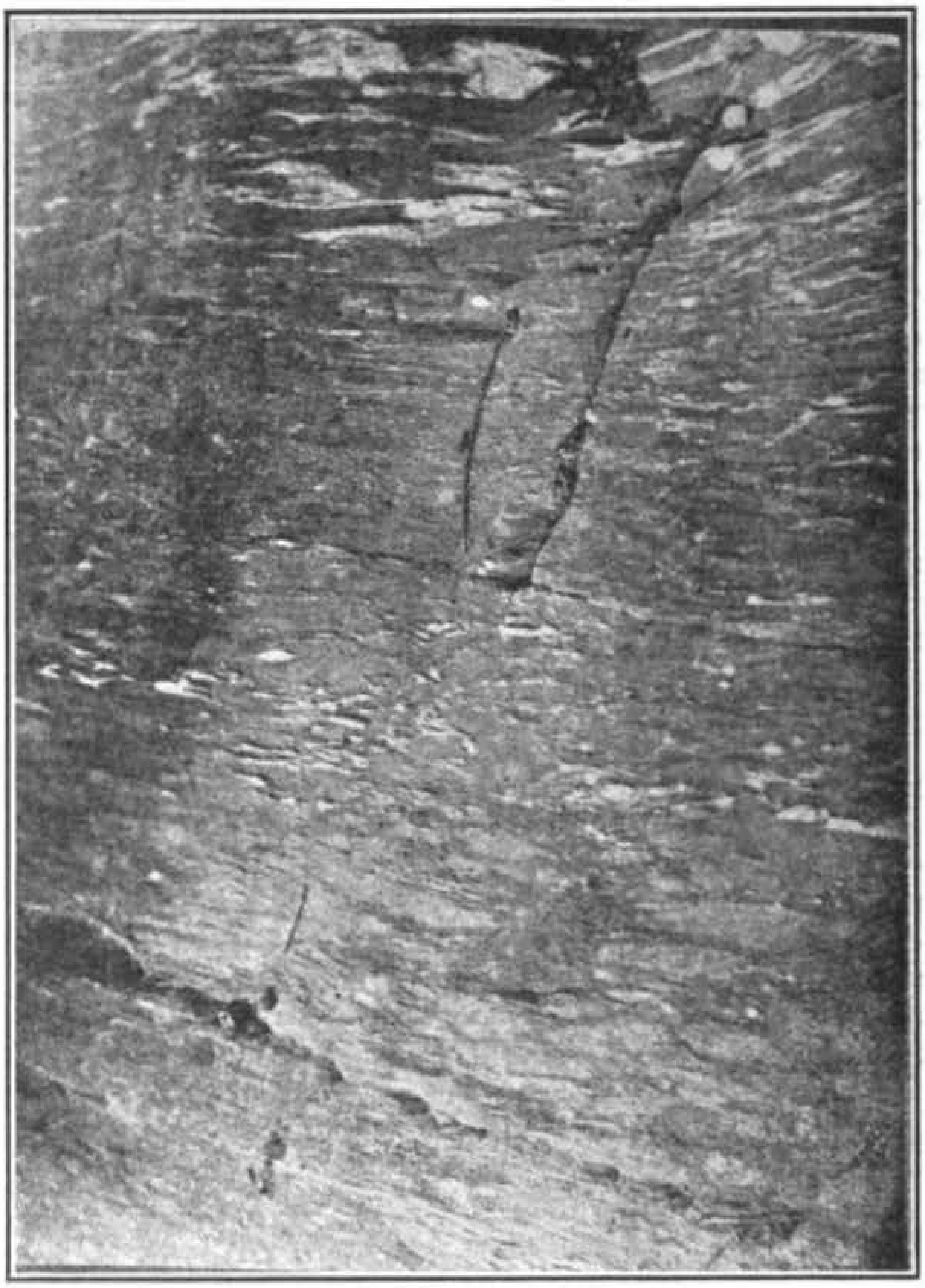


Fig. 11.—Secondary Jaspilyte. Upper Keewatin, Tower.

evidently derived as a debris from the great greenstone. The strata of this schist stand nearly vertical, but non-conformable on the greenstone just mentioned.

THIRDLY, A great series of other fragmental rocks, some very fine and some coarse. Many of these strata can be called graywacke, and many others are as fine as slate, and even as flint. These sediments sometimes appear like quartz porphyry.

While these are the principal types of the rocks in this formation, they are not always distinct and plainly characterized, but they grade into each other with all conceivable intermixtures. Sometimes the green schist element in the form of chlorite is mixed with the graywackes, or comprises a large proportion of them. Such a rock has been called "greenwacke." Sometimes the green schist is permeated by fine chemical, yet granular, quartz. Sometimes the chloritic element in the schist is rather micaceous, with a silky luster, but having still a light green tint. Sometimes the whole formation is converted to a metamorphic rock, forming mica schist, gneiss, hornblende schist and related rocks. This condition usually extends to the formation of granite, syenyte, dioryte and a number of massive igneous rocks, which are seen to penetrate the original rocks as dikes. When the greenstone itself is thus affected by metamorphism and fusion it seems to have given rise to diabase and gabbro, which also can be seen to pierce the original rocks in all directions and which sometimes overflowed at the surface, forming traps.

Now this eries of rocks with their variations, as a whole, cannot be found outside of the Archean. They cannot be found in the Mesabi formation.

6. **The Vermilion range ore.**

If we note specially the ore of the Vermilion range, we are at once impressed with the fact that it is a "hard" ore. This is exhibited at Soudan, its chief impurity being quartz. It is a characteristic red hematite. The ore at Ely, as exhibited at the Chandler mine, you may consider an exception, as it was called a "soft" ore. But it is no exception. It was at first in the form of hard jaspilyte as at Soudan. It had been crushed into small pieces, but each piece was hard as the Soudan ore. This shattered condition of the Chandler ore was due, probably, to movements of the earth's crust, caused by earthquakes. It is to be remembered that an enormous lapse of time passed between the formation of the ore and the close of the great Keweenawan age, and that during the Keweenawan age northern Minnesota was convulsed by the most profound earthquakes and by volcanic action.

7. **Two parts in the Archean.**

I have mentioned already the division of the Archean into two parts, the Lower Keewatin and the Upper Keewatin, and the existence of jaspilyte also in the upper member. These two great parts are entirely similar in composition and in posé, but they are separated by a great conglomerate, the Ogishke conglomerate, which belongs in the basal part of the Upper Keewatin and marks a great nonconformity between the two parts. Aside from the existence of this great conglomerate, it seems as if the processes of rock-making continued the same from the Lower Keewatin through the Upper Keewatin. What may have been the cause of this great conglomerate is entirely problematical, but it has been suggested by Prof. Coleman that it is of the nature of a glacial moraine, which, if true, would carry glaciation back almost to the commencement of geological time.

8. **The Mesabi Iron Range.**

I have now described in a very synoptical and incomplete manner the Vermilion Iron range, its rocks and its ore. We turn now to the Mesabi range. It is my purpose to show you the great differences between these ranges. We do not have to study the Mesabi range very long before we learn that its rocks are younger than the rocks of the Vermilion range, and that they lie nonconformably on the vertical strata of the Vermilion range, and almost in a horizontal attitude. This was illustrated in the section shown, extending from Tower southward to the Gogebic range in Wisconsin, and will be illustrated by several views that are to follow.

(12) At the Mahoning mine at Hibbing this photograph was taken, about three years ago. It shows the north wall of the great pit, consisting of hematite ore in thin strata. Notice the irregular knotty structure of the thin strata. There is no sharp transition between the ore and the rock, like that in the Vermilion range, but the rock itself changes into ore, and the steam shovel shifts its direction only when the grade of the ore is too low. Both ore and rock are so soft that for the most part they can both be excavated without blasting, though sometimes the ore is first shattered by a powder blast. The steam shovel is then sufficient.

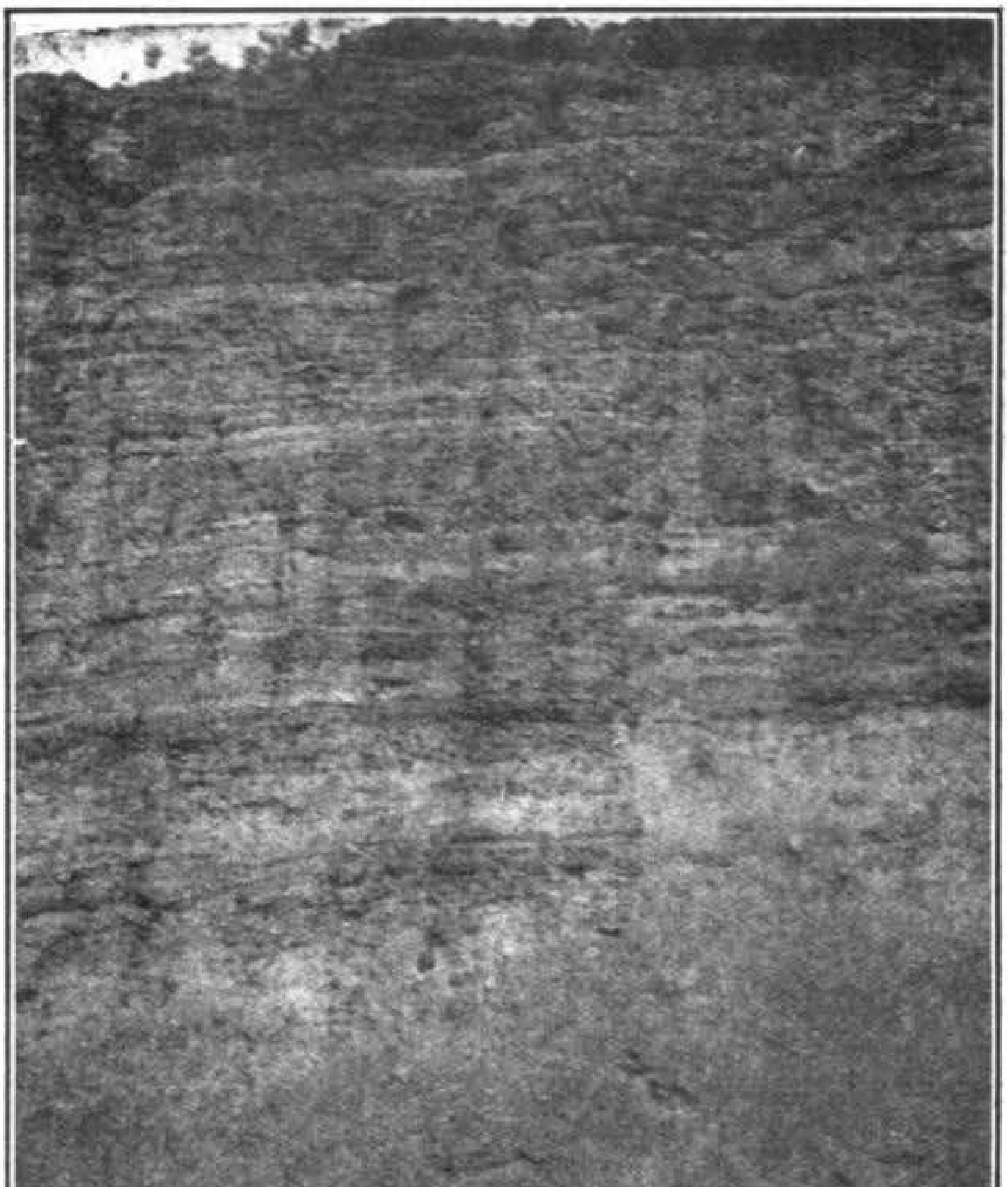


Fig. 12—Structure of the Mesabi Ore at Hibbing.

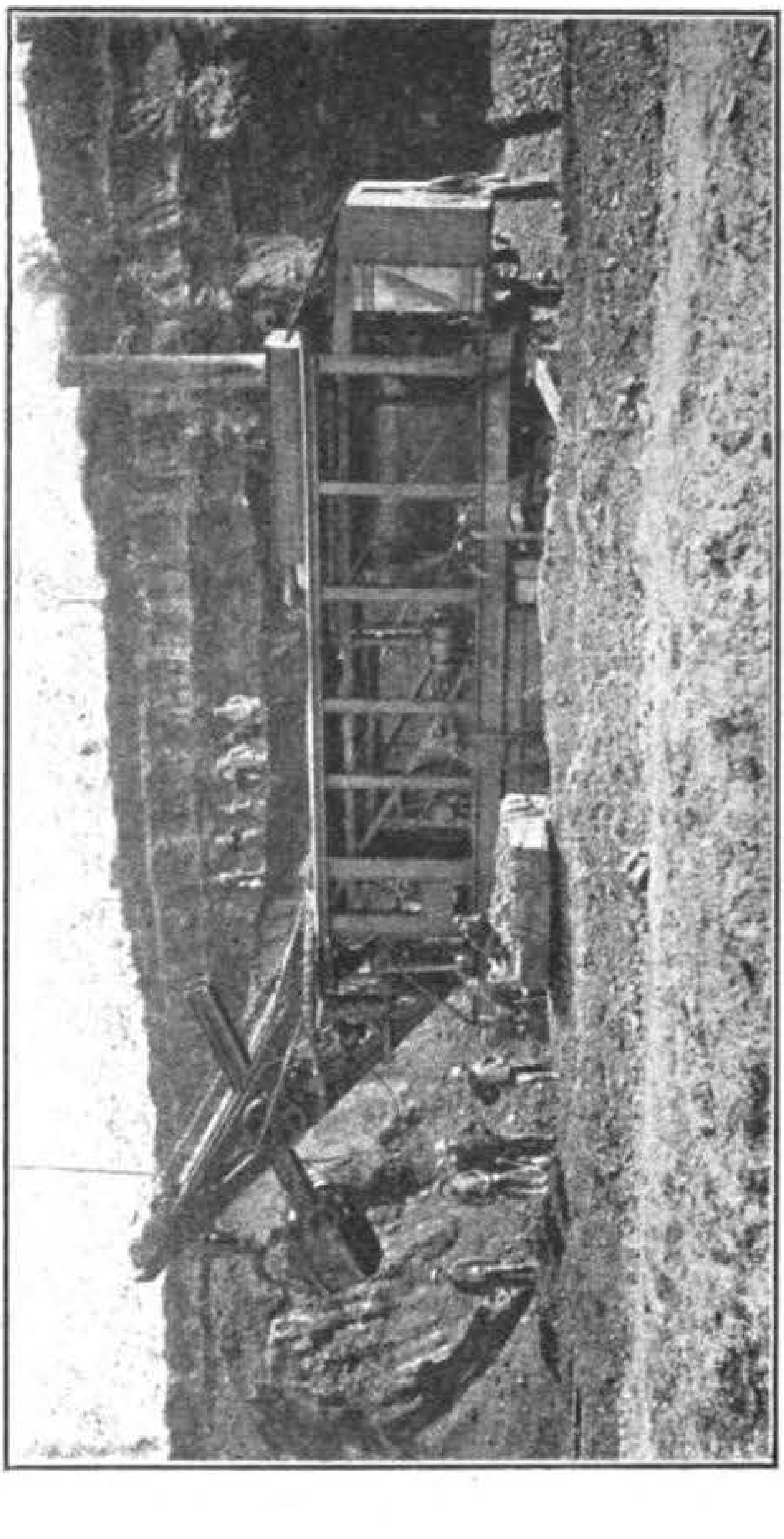


Fig. 13—Steam Shovel at Mountain Iron Mine.

(13) Here you see the steam shovel at work, at the Mountain Iron mine. From the mine the ore is dumped immediately onto a railroad train.

(14) This is a profile section showing the Mesabi ore and its rocks lying upon the greenstone which is the prevailing rock of the Vermilion range.

(15) This shows the same, but here the massive greenstone of the Vermilion is replaced by green schist and gneiss. The quartzyte seen at the bottom of the profile is the lowermost rock of the Mesabi range.

(16) This is a section drawn from nature, illustrating the conditions at the Mountain Iron mine when the ore was first discovered. The outcrop of rock at the left attracted attention and was explored by more or less excavation. It showed some iron ore, and was believed to be a "capping," so-called, of a bed of ore. But no good ore was found in it nor about it. Then a test pit was sunk, at some distance toward the south. This pit struck rich, soft hemetite ore, which, on being drifted toward the north showed that it was underlain by quartzyte, and also, later, was found to grade insensibly into a rock, here shown in outcrep, which was called taconyte.

(17) The relation of the ore to this taconyte was for some time a great puzzle. The ore was found overlying it, and underlying it, and sometimes the ore was found to be embraced within the taconyte, in pockets and large lenses, as seen in this profile section. It required long and careful study of numerous pits, and of the mines that were later opened, to prove conclusively that the ore was produced by an alteration of some rock, of which the taconyte was its present representative.

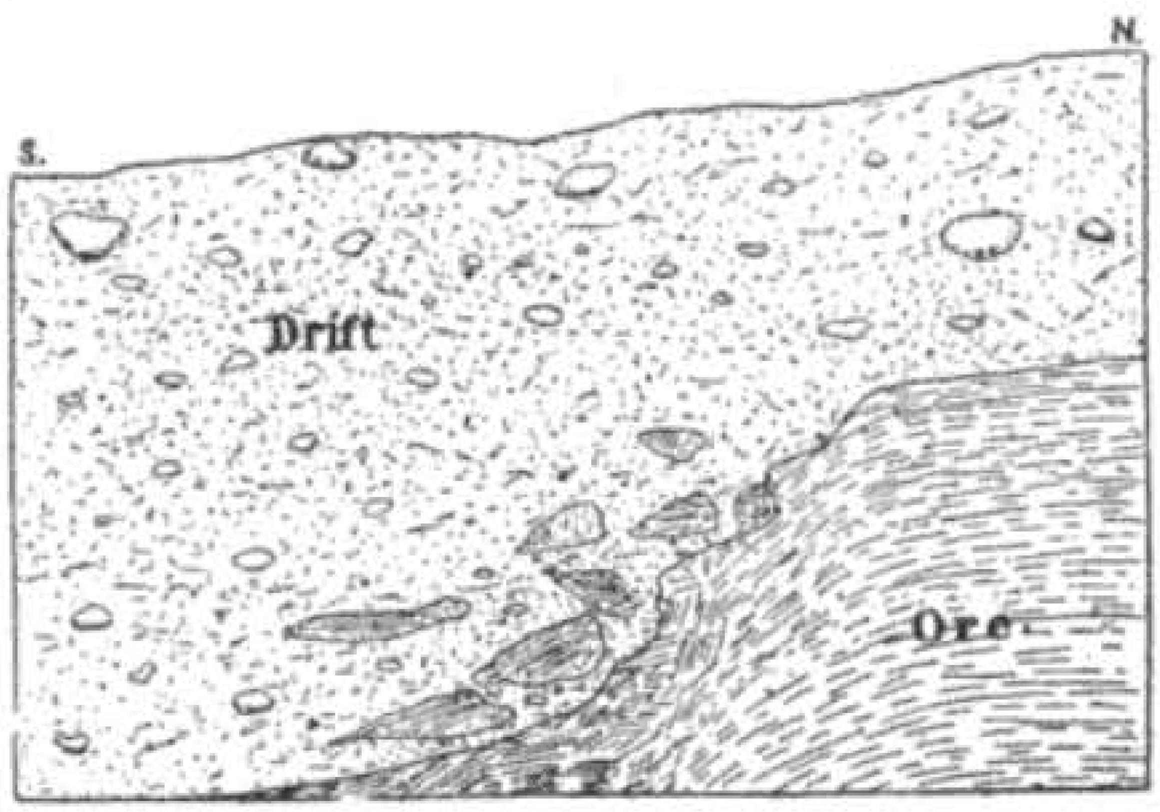


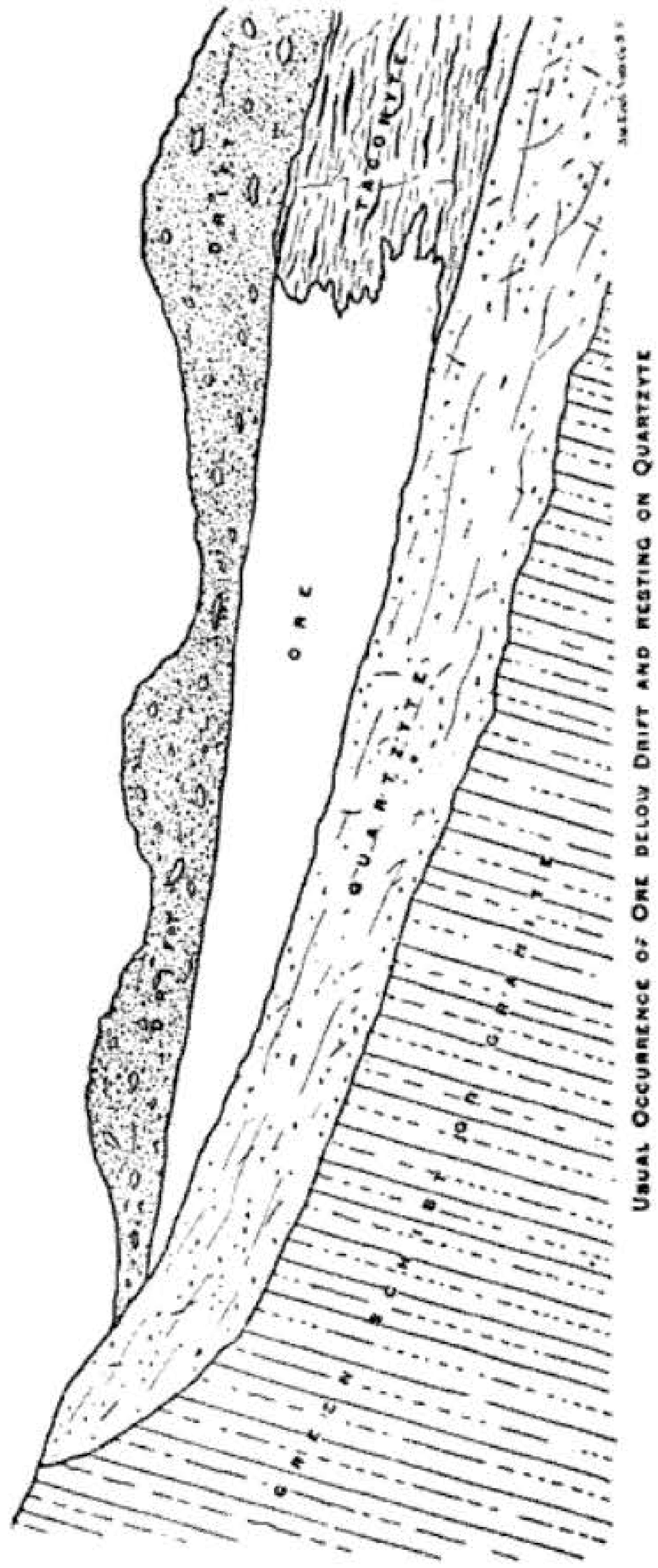
Fig. 18—Mesabi Ore Disseminated in the Drift.

(18) This view shows the manner in which the ore is broken down and disseminated in the drift of the region.

9. **The Rocks of the Mesabi Iron Range.**

If the two ranges differ in geographic location, and in the attitude of the strata, and in the nature of the ore which they respectively contain, yet the most striking feature of the Mesabi rocks is their simplicity and uniformity of composition, as contrasted with the complexity of the rocks of the Vermilion range. If the taconyte

Fig. 14—Mesabi Rocks Nonconformable on the Archean.



Usual Occurrence of Ore below Drift and Resting on Quartzyte

Fig. 15. Mesabi Rocks Nonconformable on Schist and Granite of the Archean.

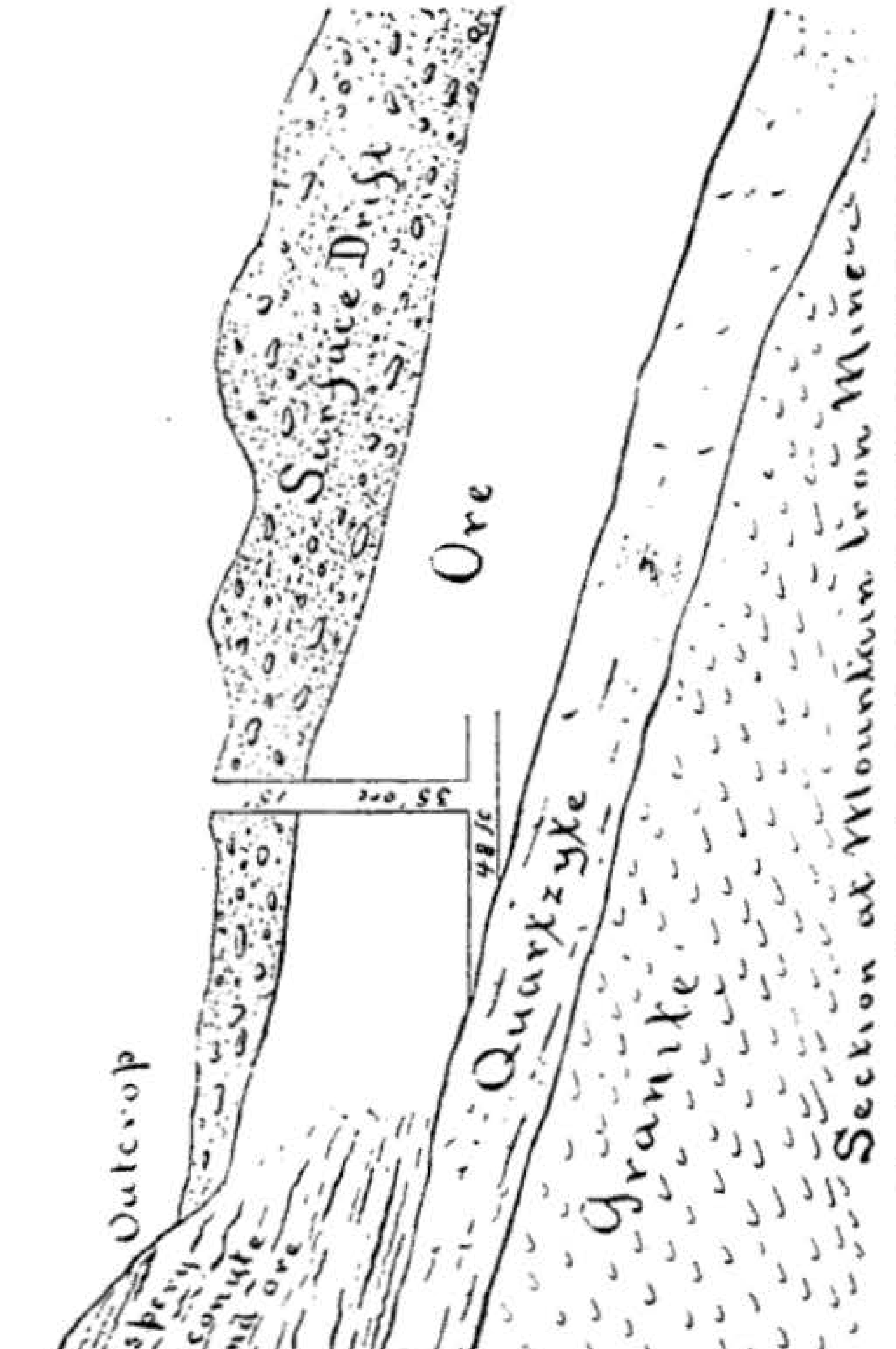
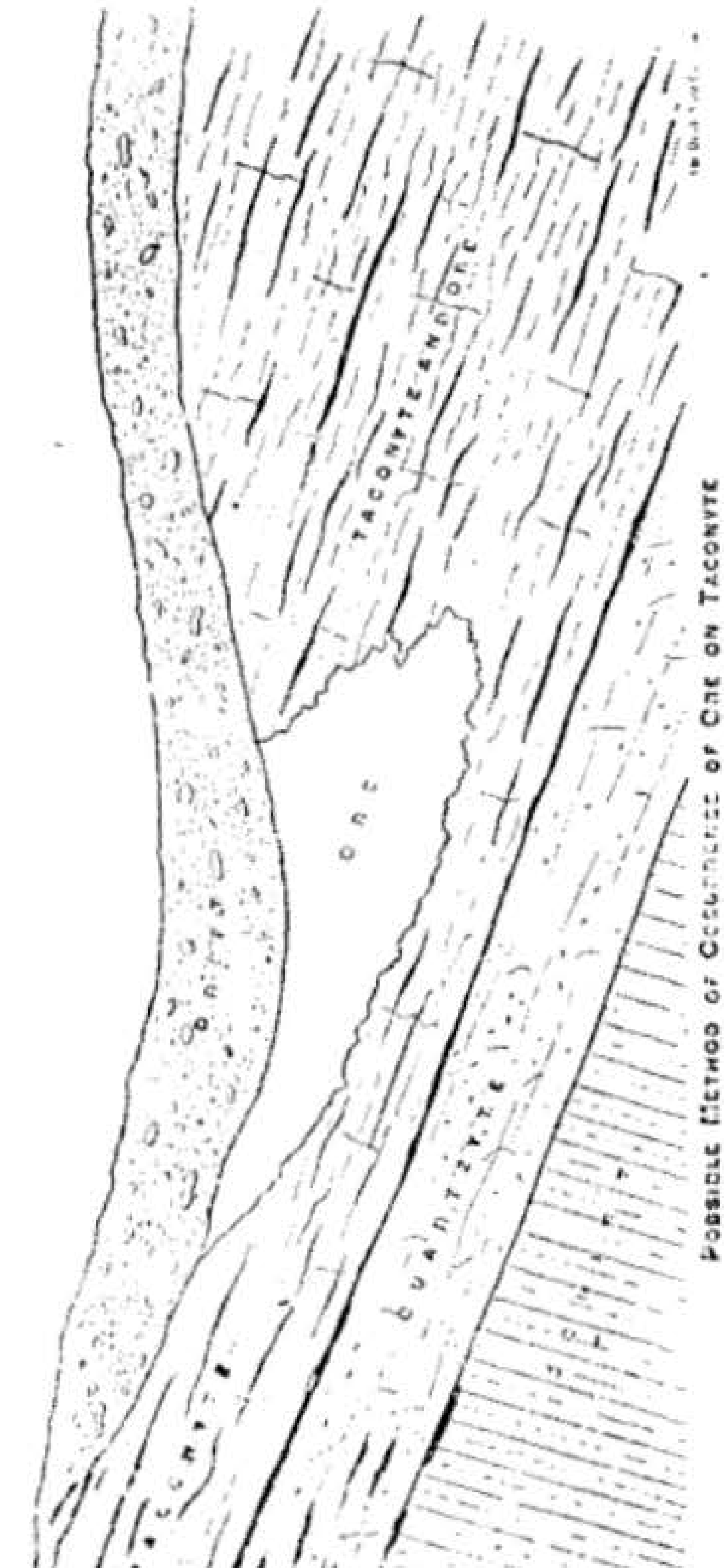


Fig. 16—Ore, Taconyte and Quartzyte of the Mesabi Nonconformable Over Granite.



Possible Method of Occurrence of Ore on Taconyte

Fig. 17—Ore Embraced within Taconyte.

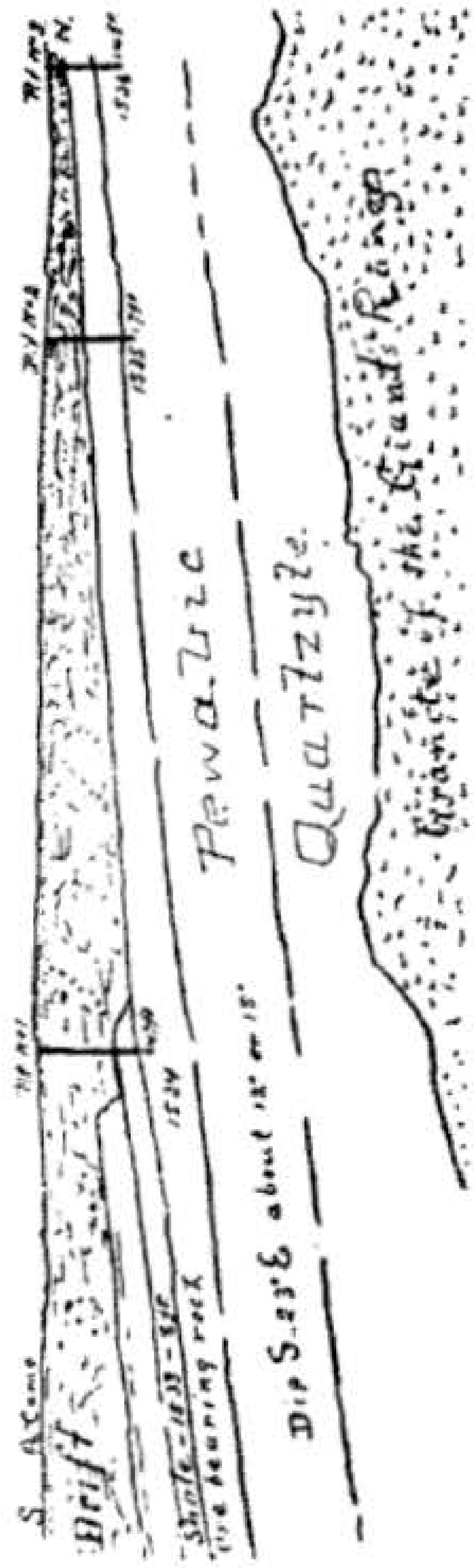


Fig. 19—Showing Red Shale Lying Above the Ore at the Diamond Mine

be considered simply a phase of the iron ore, there are but two rocks in the entire series of the Mesabi section, viz: quartzyte and slate. By instituting minute distinctions certain varietes of these two might be called different rocks. For instance, the quartzyte, which is at the bottom, is sometimes a conglomerate, and the slate which is usually dark colored or even black, is sometimes purplish, or even red, and so soft as to be more correctly called a red shale, or paint rock.

The significance of this red shale has but lately been understood, and even its existence was overlooked. It was first seen by the writer at the west end of the Mesabi range where it was penetrated to the depth of eight feet and was found lying on ore-bearing rock, the latter resting on the well-known basal quartzyte. This was in 1888, and the diagram published at the time, in his seventeenth report, is seen in the following slide.

(19) Section at the Diamond mine at the west end of the Mesabi range, showing red shale lying above the ore.

A similar red shale can be seen at the east end of the Mahoning mine, at Hibbing, where it lies at a stratigraphic horizon which furnished a large amount of ore at a short distance further west, in the pit of the great mine. This red shale cannot be distinguished from the red shale of the Keweenawan seen at many places along the shore of lake Superior, and in the lower valley of the St. Louis river near Fond du Lac.

10. The Popularities of the Mesabi Ore.

Without dwelling on the significance of this red shale, at this time, we will now briefly notice the Mesabi ore itself. After what has been stated as to the easy mining methods, it is hardly necessary to say that it is a soft granular ore. If we inspect it closer we find that the granules sometimes are made of concentric concretionary shells. Some of them are roundish, and some are parts of spheres that have been broken. Sometimes these spheres are much increased in size, and are then not concretionary. They are shaped like pebbles, evidently water worn, and they are in such numbers that they form thick beds of conglomerate. As they still consist entirely of hematite such conglomerate beds have been extensively mined by the use of the steam shovel. This is particularly true at the Mountain Iron mine, where the bed of conglomerate is at least a hundred feet thick. It is to be inferred from this gradation that the fine and the coarse were from the same source, and have suffered a similar history—in other words, that they have both resulted from an identical change to hematite from some earlier condition of the parent rock.

It is not warrantable here to rehearse the steps of the long research through which this investigation has been carried—having for its end the proper answer to the question—What was the nature of the original rock the alteration of which produced the Mesabi iron ore? In other words, what was the origin of the Mesabi ore?

1. **Igneous Rock in the Mesabi Range.**

Near the close of the late Minnesota survey it was found, at the east end of the Mesabi range, at Gunflint lake, that the Mesabi rocks contained a considerable amount of volcanic elements. Some of this volcanic element was in the form of ragged and rough pieces of volcanic breccia mainly changed to flinty and jasperoid rock, and some was yet glass—an old volcanic glass. As the study progressed, it was found that such volcanic glass was the main constituent in the Mesabi at the west end of the range, really composing the bulk of the so-called black slate. It was found that this volcanic material had been rapidly accumulated, but that much of it was in the form of sand, more or less rounded by friction. It was found that this volcanic sand had suffered alteration, at the horizon where the ores exist in abundance, and by chemical changes and transportion underground, had given rise to various new minerals. These new minerals were sometimes crowded together in the strata, and sometimes were gathered in large amount in places by themselves, and composed strata of considerable thickness. These minerals are:—hematite, quartz, calcite, kaolin.

The hematite, it is needless to say, is the soft ore of the Mesabi range. The quartz is the fine granular silica which has been called (incorrectly) chalcedonic quartz. The calcite is that which, in rare cases, constitutes thin and lenticular beds of limestone. The kaolin is found also to constitute beds, several feet in thickness. Now I have not mentioned several minor minerals such as actinolite, sphene, mica, which are in microscopic amounts, but they ought to be mentioned because they are characteristically produced by the alteration of basic igneous rock.

I have omitted, also, to mention another important product of this alteration, viz: a green, rather soft, substance which has been named greensand and greenalite.

This igneous character of the original rocks of the Mesabi range has recently been discussed anew in the "Proceedings of the Lake Superior Mining Institute." Some of the characteristic outward aspects of this rock will be shown.

(20) The basaltic jointage seen in the rock cut by the railroad in the approach to the Oliver mine. Nothing but the cooling of heated rocks is known to produce such a jointage. It can be seen in any place where massive igneous rock has been allowed to cool. It sometimes occurs also in non-igneous rocks that have been heated by contact on igneous rocks, as in the conglomerate of Ogishke Muncie where affected by intrusive granite. This is an infallible sign of great heat and slow cooling.

(21) As the igneous rocks of the Mesabi range were largely of the nature of surface lava, so several of the structures of trap rock have been observed. This view gives an illustration of the structure known as "ropy structure." When a mass of liquid lava has become cooled so as to be covered by a thin scum or skin, if the molten part continues to move this skin of semi-cooled lava crumples up on the surface in the same manner as the crumpling of cream at the edge of a pan as the milk flows out from under it. Such a crumpled mass of trap may be several inches in thickness. The view shows a small fragment.

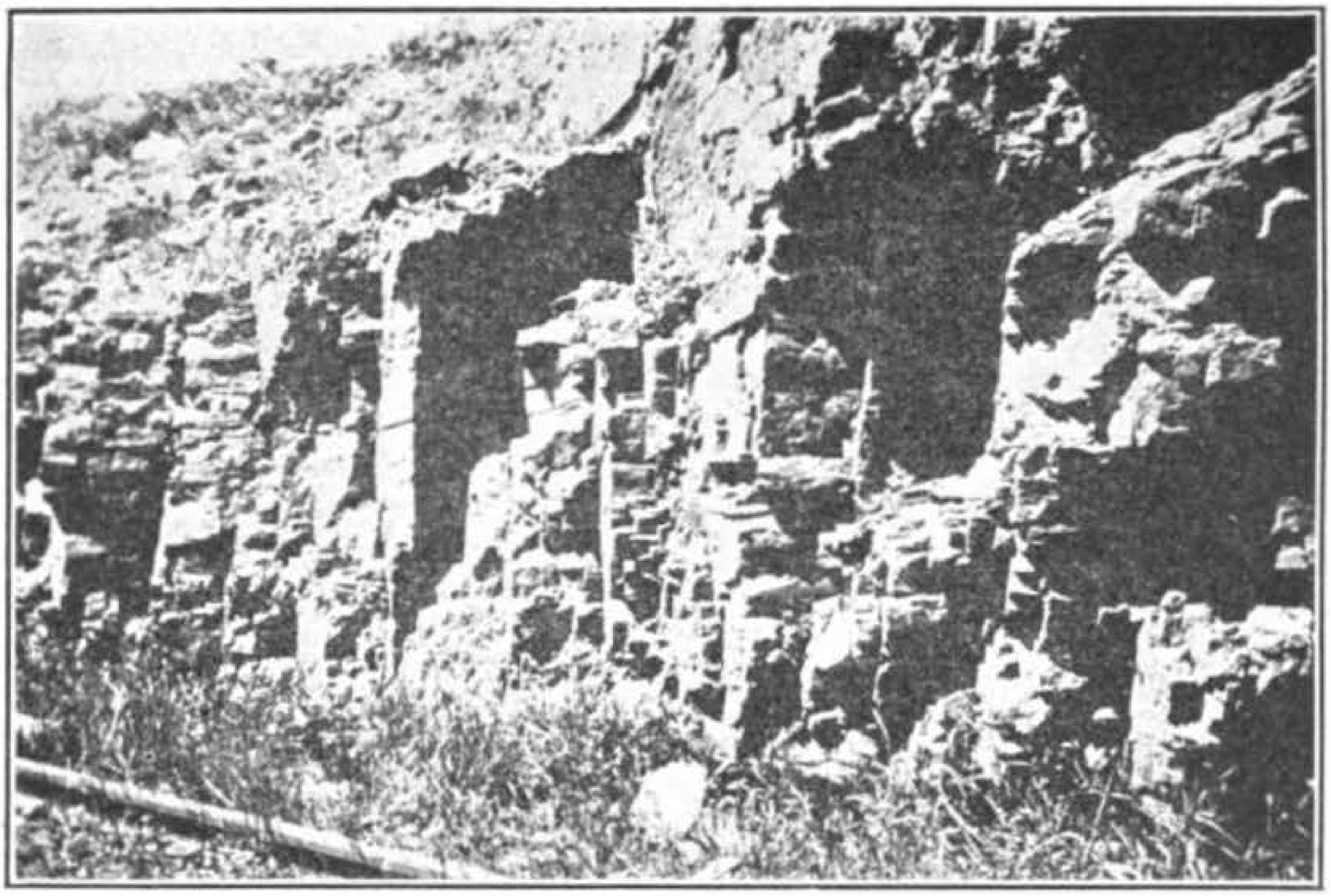


Fig. 20—Railway Cut in Approach to the Oliver Mine, Virginia.
(After Leith)

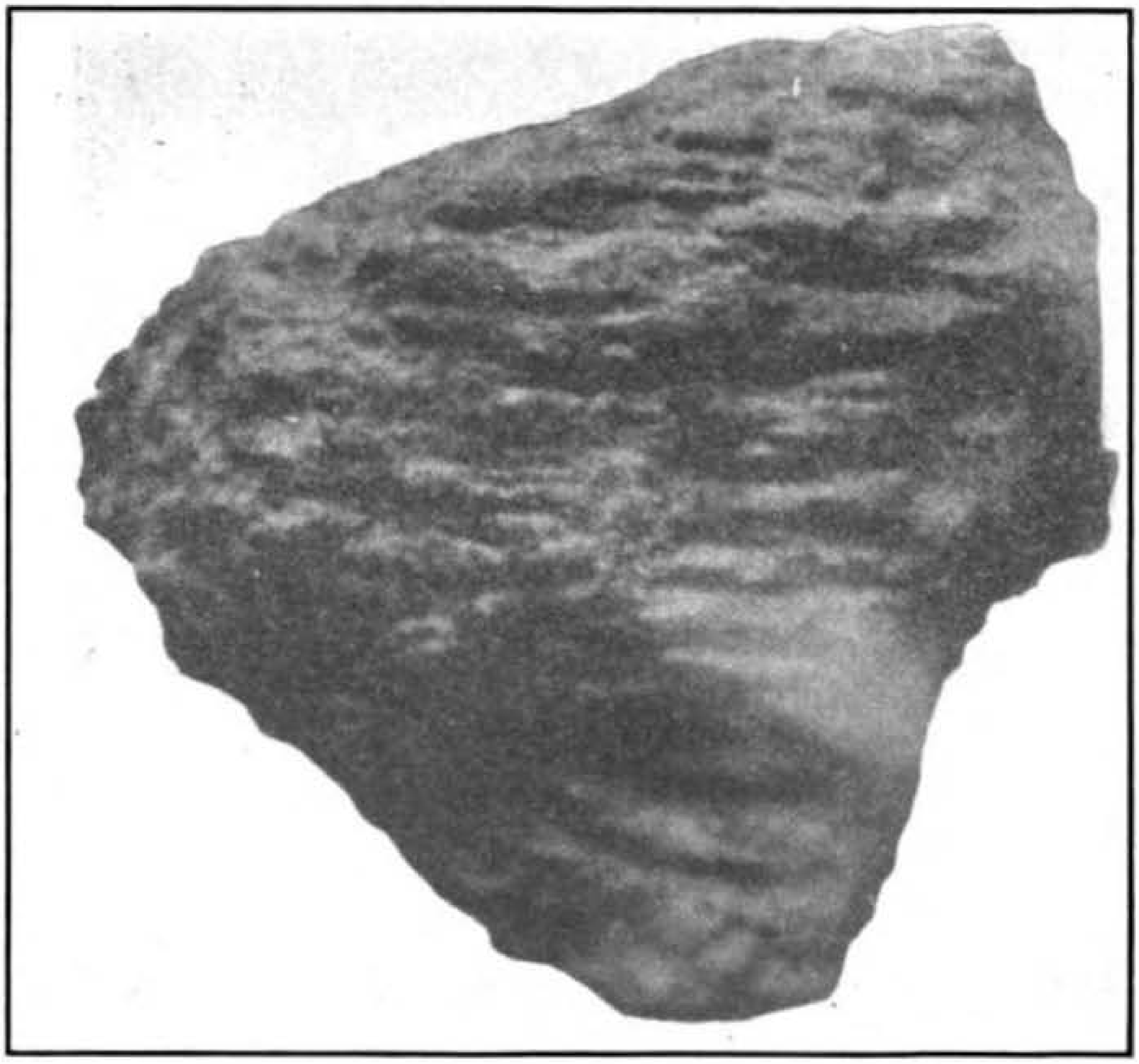


Fig. 21—Ropy Structure Seen in the Mesabi Ore.

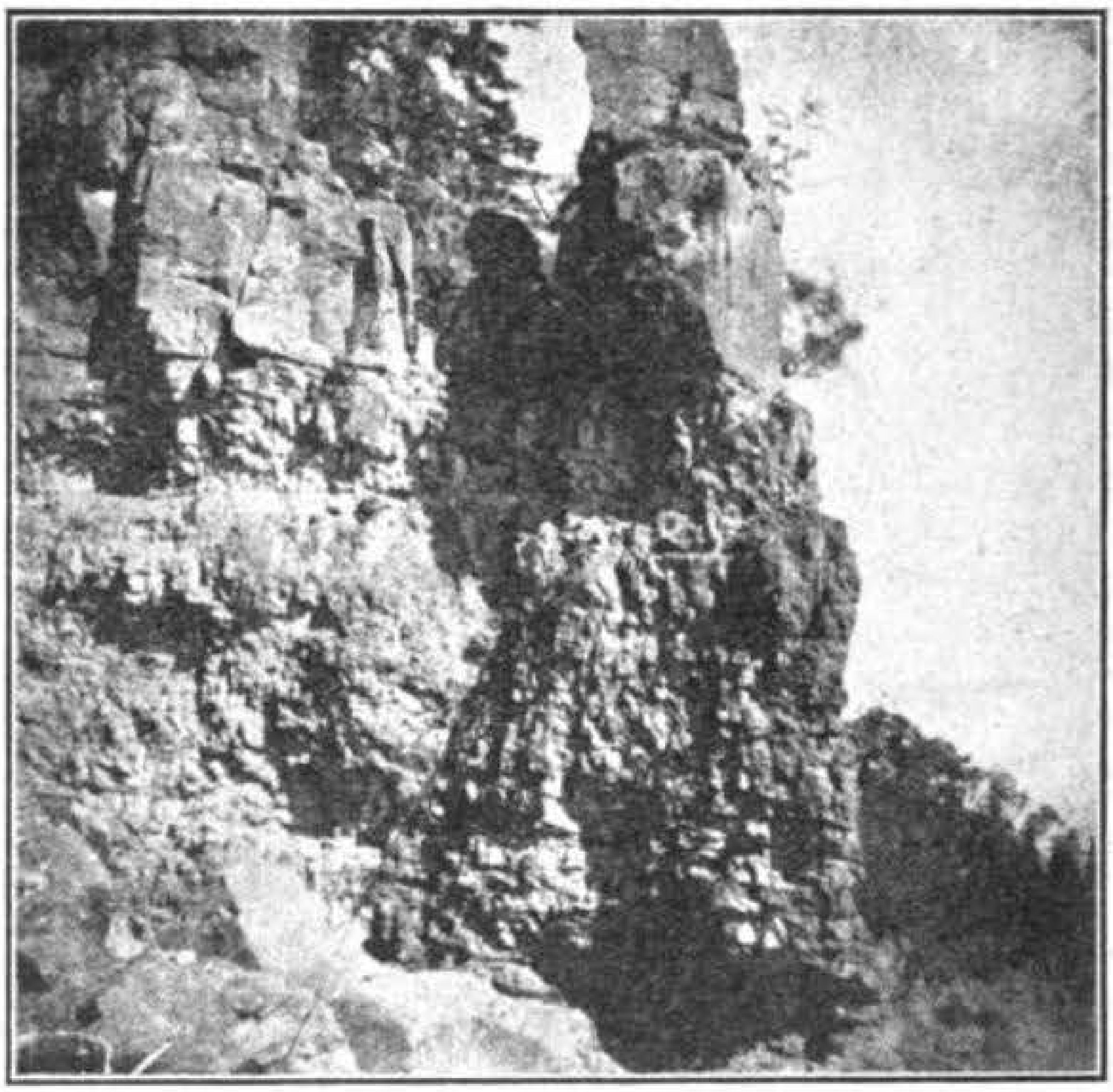


Fig. 22. Rock Bluff of the Keweenawan.

(22) This view, although taken from the igneous rocks of the Keweenawan on the shore of lake Superior, also illustrates the structures seen in the mines and other excavations of the mining region of the Mesabi, and especially at the Mahoning mine. The central part of this figure, showing the crumbling igneous rock, is like the crumbling walls of the Mahoning mine.

Other obvious igneous structures that have been described in the Mesabi mines are amygdaloid, bomb-like balls supposed to have been volcanic bombs, sheeting and jointing characteristic of lava, and "purgatories," such as are seen along the Lake Superior shore.

12. **Microscopic Characters.**

. The most interesting, and at the same time the most indisputable evidence of the igneous nature of the original Mesabi rocks is microscopic. It is getting pretty close to the subject, when you examine it microscopically, and it is not possible to go into these characters, except to speak briefly of one of the most important features. I mentioned that one of the new minerals that were formed by the alteration of the volcanic sand is

Fig. 23—Structure of the Iron Ore Grains of the Mesabi Ore.

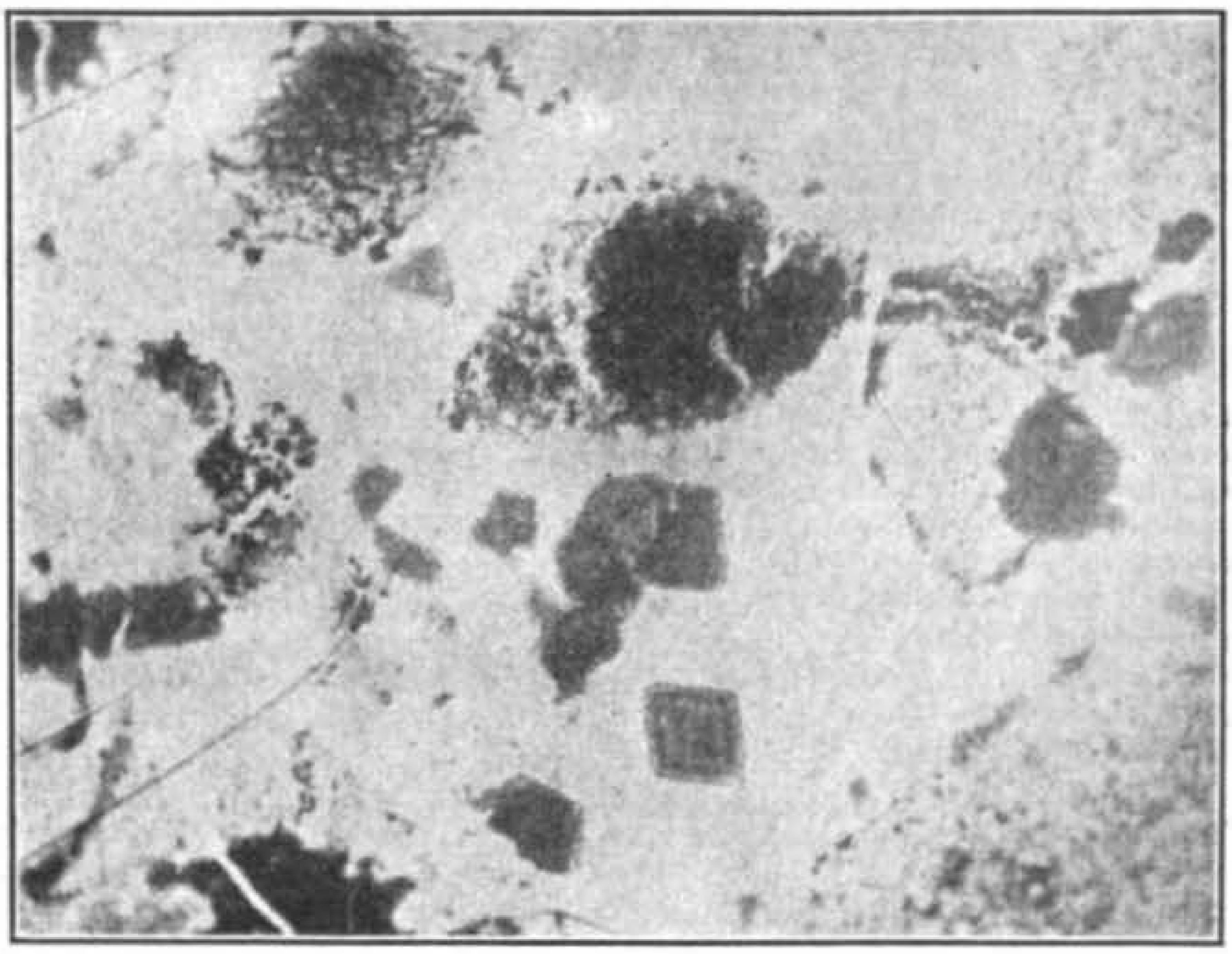


Fig. 24—Distribution of Calcite Crystals in Thin Section.

13. **Greensand or Greenalite.**

When this green substance was first discovered it was thought to be the source of the iron ore, and was called glauconite, but when it was found to differ from glauconite a new name was given to it. viz: greenalite, although still believed to be the source of the iron ore. This green substance is not abundant, but in reality is quite insignificant in amount. The actual relation of this substance to the iron ore can be seen only when examined microscopically. It would be too long a story, and unadapted to this audience, to detail the method of this examination. Suffice it to say that this green substance has nothing to do with the origination of the ore It is itself a secondary product, coordinate and parallel in its history with the iron ore itself, and with the limestone and the quartz. Its intimate relations with the iron ore and quartz, showing its independent course of development from some other source, can be traced out beautifully in microscopic thin section.

(23) I call your attention to this view. It shows the aspect of the Mesabi iron ore grains, as they appear in thin section under the microscope. The most of this slide is secondary quartz. The round grains composed of several shells one within another are partly made up of ore and quartz, and partly of the green substance mentioned. These substances are independent of each other. They do not blend, and rarely mix. They are like separate layers of separate minerals in a geode. No one of them can be said to be the source of the others, but it is evident that they had a common source outside and entirely separate from the geode itself.

Chemically it has been found that all the elements of the Mesabi rocks, both iron ore and quartz, as well as the green sand, and the limestone and the kaolin, can be derived from the volcanic sand of which those rocks almost wholly consist. It is reasonable to suppose, from all the facts, that a series of active volcanoes existed about where the Mesabi range now is known and that their products fell into a heated ocean, whose waters attacked the debris, dissolving the uncrystalline glass and distributing the results of such solution in favorable places, here forming beds of quartz, here of kaolin, here limestone and here of iron ore.

(24) Another microscopic thin section shows the prevalent manner of disintegration of the volcanic sand. As in the last the most of this slide consists of quartz. It is invisible in the slide, but some disintegrated grains of volcanic glass sand still show their outlines, though composed mainly of iron ore. The chief purpose of this view is to show the crystals of calcite which here are tightly embraced in the quartz, and which must have originated at the same time as the quartz, and doubtless from the same source. Such calcite, when abundant enough, forms the thin beds of limestone which are found near the bottom of the black slate of the Mesabi range.

14. **The Cuyuna Range.**

But you may by this time impatiently ask: What about the Cuyuna range? That is a very live subject to Aitkin. Is it entirely isolated from both the Vermilion range and the Mesabi range, or is it an extension from one or the other? Is its ore like that of the Vermilion or like the Mesabi ore? It is evident that it is necessary to be able to answer such questions before any intelligent exploration in unknown areas can be carried on. Without a correct understanding of how the ore lies in the formation much money may be wasted in fruitless search in barren rock. If the lay of the ore in the rock is understood a few crucial drill holes would, in numerous cases, be sufficient to settle the question.

If I am not mistaken a casual comparison of the Cuyuna range with the description now given of the other two ranges will be enough to show whether the Cuyuna ore is in rocks of the Archean or in rocks of the overlying Taconic. Let us ask a few questions, **first:**

As to the ore, Is it a soft ore like the Mesabi, or a hard one like that of the Vermilion range? If it is soft, is its softness due to the crushing of an ore which was originally hard, like the Chandler ore? What are its impurities—silica, phosphorus, manganese or sulphur, and is it hydrated, so as to make it limonite? Does the ore graduate in coarseness in one direction so as to become a conglomerate, and in the other so as to be a paint-rock, or red shale? Is the ore granular, and does it grade into a rock such as that called **taconyte** on the Mesabi range?
second—

As to the rocks in which the ore lies

Are the rocks nearly or quite vertical or nearly horizontal? Are they crystalline or fragmental? Are they greenstone, or any of the forms of greenstone schist? Are they associated with mica schist or with granite? Are they black slate? And if of black slate do they consist largely of volcanic debris? Is there a large amount of jasper associated with the ore?

In the light of our present knowledge of the Cuyuna range some of these questions cannot be answered decisively, and some of them are perhaps not sufficiently distinctive. That is, if answered the answers might be equally applicable to the Archean or to the Taconic. Such, for instance, is the question whether the ore is generally hydrated, so as to make it limonite. Indeed an answer to that question, based on what we know at present of the two ranges, might be entirely misleading, for we do not know from anything in Minnesota, whether the ores of the Archean are ever limonitic, but we do know that the Mesabi ore is sometimes limonitic to a marked degree. Hence since the Cuyuna ore is markedly limonitic the answer would show an agreement with the Mesabi, and tend to prove that the Cuyuna ore is of the age of the Mesabi. If we go outside of Minnesota, however, we find that iron ore from the Archean, in the Lake Superior region is sometimes largely limonitic, as in the Michipicoten region where, at the Helen mine, the bulk of the ore shipped is limonite instead of hematite. Hence the fact that the Cuyuna ore is limonitic, might be indicative of either the Mesabi or the Archean

All of the other questions, however, carry with themselves, and in their answers, more or less import touching the main problem i. e. whether the Cuyuna range is of the Archean or the Taconic. The following answers can be given to the foregoing questions:

As to the Ore.

The ore is hard, but less hard than the Vermilion ore. It carries considerable phosphorus, and occasionally much manganese. In general, so far as exploited, it is nonlbessemer. Sulphur is present in the gangue, but not notable in the ore itself.

The ore is principally limonite.*

The ore is never conglomeratic but is associated with some paint rock. This paint rock is not known to be a fragmental shale, like the paint rock of the Mesabi, and is comparatively scant.

The ore is not granular, but massive, previous to mining, and the rock taconyte has not as yet been met with.

As to the Associated Rocks.

The position of the formation is nearly or quite vertical. The rocks are metamorphic, and sometimes may be called crystalline.

They are largely of greenstone, or green schist. Both granite and a fine silky mica schist are found on the Cuyuna range, the latter in many drill holes.

In some instances a carbonaceous (graphitic) black slate has been found on the Cuyuna range, but its structural relations are unknown. It may be due to early igneous action, but it has not been found to be referable to volcanic debris, like the slates of the Mesabi range.

The ore is sometimes associated with jasper, but not to a marked extent. It is identical with the jaspilyte of the Vermilion.

These answers are based on what is now known of the Cuyuna range, and are liable to correction as new discoveries are made, but it is not at all likely that such discoveries will change the general purport of present evidence.

It is hardly necessary to state that the testimony of these answers is overwhelmingly in favor of the Archean age, and hence in favor of the Vermilion range. It would be vain, therefore, to search for the Mesabi ore, or any ore like the Mesabi ore, in the Cuyuna range as now developed.

There is still one important proviso that ought to be mentioned in favor of the possible discovery of the Mesabi ore on the Cuyuna range, viz: at some places on the Cuyuna range some of the red shales, and the igneous conglomerates characteristic of the Mesabi ores, have been discovered by diamond drilling. Such red shale was found near the west end of Dam lake, having a thickness of thirty feet, and the igneous conglomerate (or breccia) was found at eight miles east from Brainerd. These indicate the extension of the igneous rocks of the Mesabi over some part of this region, and it would be wise for future explorers to give careful heed to these discoveries, to the end that an extension of the Mesabi ore may be brought to light.

The first discovered of the Iron ranges was Marquette, and at that place for some years ore was mined from rocks of both ages before it was found that both existed in the limits of the range. It seems very likely now, that the Cuyuna, the newest of the iron ranges discovered, may duplicate Marquette in having both represented, and that Aitkin fifty years hence will be as far-famed as Marquette is today.

---

* Latterly the ore of the Cuyuna has been found to consist largely of hematite.