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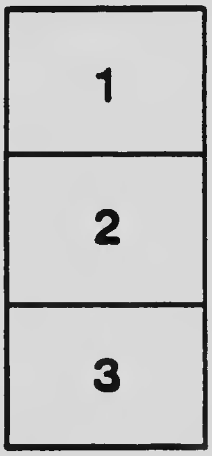

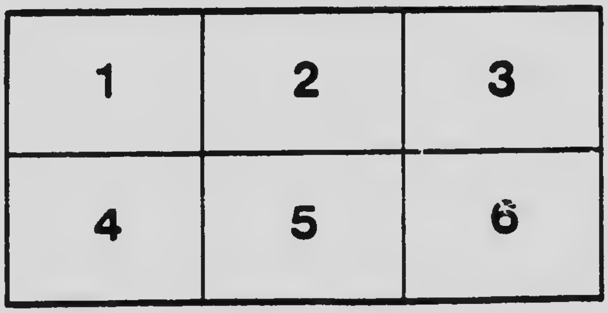

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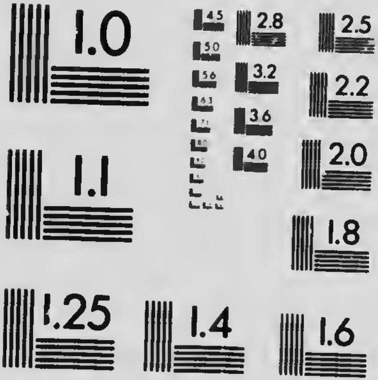

The Iron Ore Deposits of Western Ontario and their Genesis.

By F. Hille, M.E., Port Arthur, Ont.

If we consider that the world used in the neighborhood of 100,000,000 tons of iron last year, and the United States alone nearly 30,000,000 and if we picture to ourselves the space which these ores have occupied, and remember that these figures represent—especially on this Continent—only the higher grades, then it is not astonishing that everyone interested in the manufacture of iron is developing a feverish activity in the search for new resources of this raw material. We, here in this country, have been very active this season, from near and far came representatives of larger and smaller iron works, with a sprinkling of speculators mixed in. Those who did not know our iron deposits, and the rocks in which they occur, but have been here and have diligently studied them, should now have become better acquainted with them, and should know—at least to a certain extent—what we have here ; how it occurs and how it originated. I confess, however, that it is difficult for the occasional observer to become readily and intimately acquainted with both our stratigraphical and economical geology, because, our rocks represent the oldest members of the earth's crust, with not too many later sedimentary rock depositions to help us to read them like turning the leaves of a book, to enable us to grasp the subject at a glance. Our rocks are principally eruptive, and to recognize which is the older, and which the younger, and which the mineral producer, needs a long while of close study, the possession of a keen sense of observation, and also a certain enthusiasm in these researches, to overcome the drawbacks and fatigues which such a new, uncultivated, and extensive country as ours offers. My long years experience in, and acquaintance with this country, gives me perhaps a certain justification to approach the subject of this paper, which so far has found no exponent, and which seems to me to be rather timely. But before doing so, however, I have to make the reader first somewhat acquainted with the geology. He will understand more readily that which I shall say later about the genetic relation of the ores with the rocks in or nearby they are found. Let me commence at the lowest series of our rocks and continue in an ascending order.

ARCHÆN.

A. Laurentian
Gneiss and granite.

B. Huronian
(a) Coutchiching (lower) mica schists and quartz—porphyries.
(b) Keewatin (upper) chlorite, talc, hornblende and sericite—schists.

CAMBRIAN.

(a) Animikie (lower) Chert and jasper argilites.

(b) Keweenawan or Nepigon (upper) Jasper and quartz conglomerates. Sandstones, marls and dolomites.

LATER ROCKS

1. Diorites, 2. Gabbros, 3. Serpentine, 4. Syenite, 5. Granite, 6. Conglomerates, and 7. Traps.

This classification of our rock formation is the one adopted by the Canadian geologists; our neighbors to the South, classify it somewhat differently, as for instance, they bring the Animikie among the "Huronian" and this because they hold too strictly to the name which was given to the rocks occurring around Lake Huron. These rocks are for the greater part, doubtless younger than the Keewatin and Coutchiching rocks, some even Post Cambrian, but the Archæn rocks also are not lacking in that region and as it is in our vast country with its still primitive communication, nearly impossible to map down each different rock occurrence and especially where the field appearances of even many of these younger eruptive rocks is so similar to those of the north shore of Lake Superior and the coming of a new name is not desirable, the word "Huronian" therefore was adopted by us exclusively for those oldest rocks of our earth's crust which are so well developed in Canada, and so little noticeable in other parts of this continent. The United States Geological Survey has placed these oldest rocks in one group together with the much younger sedimentary rocks and has called this group "Algonkian." This would signify that they consider the Keewatin and Coutchiching to be also sedimentary rocks. This is doubtless erroneous, because most of them, if not all in our country were without question, originally eruptive rocks, changed *in situ* through heat, dynamic action and chemical agencies to what they are now.

How these steeply tilted crystalline rocks, can be placed with those much younger, mostly flat lying amorphous slates, sandstones, marls, etc., which are resting uncomformable on the former, is not readily understood. In the course of this paper, I shall therefore, always use the name "Huronian" in the same sense as our Canadian geologists.

I now come to the subject of this paper, that is, the iron ore occurrences in these western districts, and I shall place and describe them as they appear and are found in the different geological horizons.

1. Huronian: Magnetites and limonites from carbonates.
2. Post Huronian: Magnetites.*
3. Cambrian: Magnetites and carbonates, etc.

They are found in the following localities:—

Class 1. (A) The Kaministiquia. (B) The Matawin. (C) Green Water Lake.
(D) Hunter's Island deposit.
(E) Atikokan.

Class 2 (F) Green Water Lake.
(G) Head Lake.

[illegible] (H) Magnetites at the northern margin of the formation.

[illegible] and D deposits are all of the same nature, and originated through the infil[illegible]tion of hot iron and silica solutions into the fissures of a sheared chlorite schist. These fissures were still further widening through the replacement of the latter by the first. If we look at the accompanying maps 1, 2, 3, we find that these deposits form an almost continuous belt, representing a flat lying crescent whose eastern horn commences south of Kaministiquia Station, continues north for miles, turns then in a sharp curve to the Matawin River, follows this river and travels onward past Green Water Lake and Moss Township and turns then in a long sweeping curve into Hunter's Island. Along the Kaministiquia, Green Water Lake, and Hunter's Island the ore is banded, iron and jasper alternating, while along the Matawin River the iron deposits are more massive, some of extraordinary width and comparatively free of jasper. I have tried to show this on map sheet No. 2. The quality of the iron is low grade averaging from 35 to 40 per cent., the

* This class belongs doubtless to the Post Cambrian but as they form dykes in the Keewatin rocks, I have placed them close to the Huronian.

largest portion consists of an intimate mixture, and the other of a chemical combination of magnetite and silicate acid, very fine and close grained from blueish black to reddish black in color. At the eastern and western ends the iron bands when separated from the Jasper, show a somewhat higher percentage of iron, but these bands are usually not wide enough for any economical separation of both those minerals. Now it might be that there are places in these deposits where the iron is more concentrated, and the jasper replaced by iron, but only the diamond drill can disclose this. On some localities these jasper, and iron bands, are most wonderfully contorted, the general trend is with the foliation of the rock formation, but often we see long pieces turned and bent out of line, and pointing to all directions of the compass. I mentioned above that the iron deposits on the Matawin River especially so, near the "upper falls" of that stream, are of considerable width. On hill 7 three parallel running deposits form together a width of over 700 feet (*vide* map 2). A part of this iron which was formerly all magnetite, is more highly oxydized, particularly so at the north and south side, and changed into a martite, or in less technical language in an ore of hematitic nature. Considerable prospecting work has been done on these deposits, in stripping, crosscutting and diamond drilling, of the latter work several holes are down 1,000 feet in an angle of 45 degrees, and where the drill was kept with the strike of the deposit, ore was encountered all the way down and exactly of the same quality as the surface showing 35 to 40 per cent. with phosphorous, a little over the Bessemer limit. Except somebody wants a silicious ore for a mixture with pure soft iron ore, this ore will come into use after all the higher grades are exhausted, but then we could supply the world for centuries with it. For twenty miles we find this same ore in wider and narrower deposits, striking with the formation in a nearly east and west direction. These deposits when nearing the volcanic centre of Greenwater Lake become more banded with blueish black, white and red jasper and show here often, as I mentioned above, a remarkable contortion, the bands turned and twisted in every conceivable form and shape. This is doubtless produced by the later coming diorite, which can be seen cutting both the rock and the iron, which exerted pressure from different sides and ends. These iron deposits are found usually resting upon the anticlinal of a chlorite schist, and are the results of the ulterior action of an eruptive granite or gneiss whose fumerolic activity must have been not only very intense, but also of considerable duration. Then the exhalated minerals coming in contact with underground water furnished not only the contents of these iron deposits directly, but leached also a large portion of iron out of the schist and deposited it into the fissures. In confirmation of this we find that the latter rock down to a considerable depth contains only a small amount of iron, the less the nearer to the deposit, but the farther from it the more it retained its original iron contents. Diamond drill cores of rock not far from the iron gave only 2½ per cent. ferrous oxide, farther away nearly 5 per cent., and increasing in percentage the more we leave the deposits. In the same progression, the silica increases in the rock the nearer we come to the iron, which is at last 70-79 per cent Through this leaching and replacing process the field appearance of the schist near the iron is therefore more that of a creamy white dolomite. Also some minerals of secondary origin are found in the rock as well as in the iron, among several calcite is the predominating, filling out the little fissures caused by later crushing, and showing often to the amout of 6 per cent. Their existence is due to an intrusive diorite which shows in numerous dykes cutting both the schists and iron deposits, as I already mentioned, and formed along both a very interesting breccia-conglomerate. I can now leave these magnetites which are perhaps the most massive deposits of iron which the world knows and it will take centuries to exhaust.

I used above the word "Groundwater" in speaking of the genetic occurrence of this iron, now I do not apply it here in the sense of some writers who claim "that there exists in considerable depth in the earth's crust a moving body of water flowing and percolating through the rocks, leaching out therefrom the minerals, and after acquiring the higher temperature of the lower rock strata, ascending again into the cooler upper regions, owing to their isogeothermal difference, and redepositing their contents into the fissures and cracks of the rocks." Water doubtless percolates through permeable, slaty, or fissured rocks to a certain depth, but which can be in volcanic localities not very great, surely not in our country. It would therefore be erroneous to speak of a flowing groundwater in this sense, the less so, as we find most of the deeper mines nearly dry. When I nevertheless used this expression, I pictured out before me the earlier state of the earth's crust which at that time was still comparatively thin. I mean at the time when the Huronian rocks had already solidified and had at their base the still viscid present Laurentian gneisses and granites. The volcanic and plutonic activity must have been immense at that period, and especially at the commencement of the contraction and shrinkage of the gneissic magma whereby certain areas became also eruptive, so much so that this magma not only remelted the largest portion of the Huronian rocks but also became intrusive into the fissures of same, and overreached and overlapped the remaining rocks on both sides, so that the Huronian not only had to follow the contracting movements of the gneisses but had also to suffer immense lateral pressure, by which they were tilted, folded, sheared and fissured, and in the latter form principally so, at the axis of the anticlinals. This is easily recognizable in our country because we find most of the ore deposits and later dykes of other rocks at these weak points of the Huronian. These terrific pressures have been also the cause of the foliation of the older rocks. In earlier times it was believed, and many writers to this day still cling to the belief, that the Huronian rocks were produced through sedimentation and later on tilted. But if we examine their cleavages a little closely, we find still in a great number of them layers of finely crushed material of the same substance as the ones of which the rock consists. Of course, in many these foliations later infiltered mineral solutions obliterated, or changed the former crushed products to something else. Now this action by which hard, acid or basic rocks are foliated by pressure, can easily be seen at many places especially at their contact with other harder rocks, for instance—quartz veins. The walls of the rocks show nearly always, when they have been unstable laterally, a slated, foliated or gneissoitic structure and this is the same phenomenon which produced the foliation of the Huronian rocks. It is easily comprehended that the latter at that period must have been considerably shattered and open, which not only permitted the gases and fumes of the eruptive magmas to find vent through them, but also allowed the condensed water-vapors of the surface to percolate through these openings, which, meeting with those gases, were taken up by them, and deposited upwards, sidewards, or wherever they found a sufficiently large opening. There, where the rock was permeable, or rendered so by crushing, these mineral solutions would also penetrate into the wall rocks, leaching out certain minerals and leaving, perhaps, others in the former's place; but in my opinion they did not depend on these rock minerals for their vein fillings. Now these solutions I called "Groundwater," rightly perhaps so, when we keep in view the time in which these processes must have been going on; but wrongly, perhaps, when we consider exclusively the intense heat which prevailed at the beginning. At that time the meteoric waters could not penetrate into the rocks beyond a certain depth, for they would have been expelled as steam, and very likely have been so, and this steam condensed in the upper cooler strata and deposited there the minerals first, until the lower part of the fissures cooled more and more, when gradually those waters would reach the lower region, depositing the minerals in their last. At the present time, conditions are changed, and it is very questionable if we can speak of a "general groundwater," as to-day most of the channels and fissures are closed and most of the existing rocks are impermeable with the exception of some of the newer sedimentary ones, which, however, play no great role in metal mining.

I thought it necessary to make such a long deviation from my principal subject to define the meaning of "groundwater" as I applied it in its action as a mineral distributor and depositor. There is still such a great diversity of opinion about the *rôle* water is playing in the formation of ore deposits, that it is necessary for everyone who attempts to speak about it to define his theory and position so as not to be misunderstood.

Among the Huronian rocks occurs, as I indicated above, also a limonite. Prospectors have found years ago large and smaller boulders as "floats" of this ore, especially near Steep Rock Lake; only lately they have observed several localities where exactly the same kind of ore is in place. Unfortunately, it was too late in the season to go and make an examination of these deposits, but the samples brought into my laboratory allow the inference that they are derived from a siderite containing a certain amount of manganese and a very small percentage of phosphorous. Pseudomorphs of this ore gave up to 68 per cent. metallic iron and 0.001-0.004 per cent. phosphorus, 0.02 per cent. sulphur, and from a trace to 2½ per cent. manganese. In those samples free of manganese, the latter mineral and iron have separated, while the oxydation process of the original ore was going on, and deposited and formed small stringers of pure manganese in the crevices of the rock. The ore is found in a greenstone, but in what relation ore and rock stand to each other I do not yet know. I could also not state if there is a sufficient quantity for economical mining, but as soon as our country takes off its wintry white gown again I shall examine the deposit closely, and may find then, later, another opportunity of speaking more about it.

I come now to iron deposit of class 2, E, F and G. I mentioned already in a foot note that these iron occurrences belong by right after class 3, because the gabbro and peridotite rocks with which they are idiogenetic are Post Cambrian, but they form in our western district dykes in the Keewatin, the upper Huronian rocks, and are so closely associated with them that I consider it more correct to place them as I have done in following the formation step by step.

The iron deposits of class 2 originated through a "magmatic differentiation process," that is, the various constituents of the magma separated to a large extent in special groups; for instance, the Atikokan dykes contained in their magma sulphide of iron, (2) magnetic iron, (3) silicate of magnesium and calcium, (4) silicate of aluminum and sodium, then No. 1 formed pyrrhotite, No. 2 magnetite, No. 3 hornblende, No. 4 albite. Again Nos. 3 and 4 formed together to a rock as Gabbro, Nos. 1 and 2 separated into special minerals, or mixed mechanically with the rock; now we see that this class is of volcanic origin, that its constituents form pockets, and lenses of all sizes, either mixed together or partly separated, in the manner represented in map No. 3. These dykes are of similar nature to the rocks in which pyrrhotite is mined in the Sudbury country, with the only difference that the latter must have cooled slower; the various constituents here, pyrrhotite and rock minerals, had time to separate more or less perfectly, while in the Atikokan dykes, sulphur, iron and rock are more mixed perhaps owing to a somewhat faster cooling of the magma. In a transverse section of the deposit as shown in the map, we notice how irregularly the minerals are distributed, and how small the lenses, and how short the continuity of each of these is downward. They are somewhat elongated in consequence of a considerable lateral pressure which they had been subjected to, very likely by the continued folding movements of the chlorite schists and through whose anticlinal axis they are now seen protruding, a large portion of the schists on both sides of the dykes is eroded, being softer than the dyke minerals, which withstood better the oxydiation process of the times and the ploughing action of the icebergs. The structure of the different minerals is decidedly crystalline, the rock minerals appear often in large phenocrysts, while magnetite and pyrrhotite consist of smaller grained crystals in close compact masses, tough to drill, although not difficult to crush or to powder. The pure magnetite contains from 64 to 68 per cent. iron, from 0.03 to 0.01 per cent. phosphorous and from 0.5 to several per cents in sulphur, while the pyrrhotite might contain at a greater depth nickel, at the surface it is only a trace, as this is a usual occurrence in pyrrhotite deposits

The rock under the microscope shows to be a gabbro: the greater portion of it is changing into a serpentine.

The width of these dykes is sometimes considerable, the most easterly—that is the one situated east of Sabawe Lake—is, at its greatest width, about 300 feet, running out at both ends to a thickness of a few inches. The dykes west of the lake are smaller, but have the same elongated form which follows the strike of the schist foliation. On account of the peculiar nature of the ore very little pure ore could be mined and shipped directly from the mine to the works; the ore has to be prepared first, that is the rock has to be removed and the pyrites roasted.

It might be perhaps of interest to relate some experiments which I made with the Atikokan ores last year, in trying to make a commercial product out of them. I think I succeeded very well. I proceeded as follows:—(1) I ground the ore, (2) separated by magnetic separation that part of the ore containing a certain amount of rock matter. If the ore was free of the latter, I commenced directly with (3) dead roasting and followed with (4) briquetting. The latter manipulation and (3) are done in one furnace, and I received a product which is nearly self-fluxing, and, what is of special importance, it is so solid that no danger exists of the ore crumbling to dust in the furnace through its own weight and choking it up. The analysis gave 68 per cent. metallic iron, 0.02 phosphorus, 0 5 per cent. silica, 0.08 sulphur, and the rest carbon. These briquettes should be suitable for making steel by a direct process.

I return now to our former subject. As I enumerated above, we have three localities in which we can furnish sufficient proof that the iron ore originated through volcanic action, and separated from the other constituents by a magmatic differentiation process. I think I have said enough of the Atikokan iron deposit to be plainly understood. I might also mention that a tunnel was driven into the widest place of one dyke, some cross-cutting done and a number of diamond drill holes bored into the deposit, east as well as west of Sabawe Lake.

I now come to F., the deposit at Greenwater Lake. We have here something similar as described under E., with the only difference, that there is no pyrrhotite mixed with the iron and rock, and both constituents better separated from one another. We find the iron more on one side, the rock on the other, and clean iron shows sometimes with a width of 20 feet. This separation of the minerals seems to continue downwards: the rock is in general more coarsely crystallized than in the Atikokan dykes, showing that we have here a deposit which has cooled more slowly. The rock shows under the microscope to be a gabbro with large hornblende phenocrysts cemented together by plagioclase, and changing into a serpentine. The ore averages about 54 per cent iron, 0.12 per cent. phosphorus and a varying percentage of sulphur which is from surface samples not quite exactly determinable—because some particles of iron pyrites occur in the little cracks and interstices of the ore, as a secondary mineral, but usually the amount is not high enough to injure the quality of the iron. The ore underwent considerable lateral pressure; we find it therefore somewhat slatey, finer grained and intermixed with some chlorite, often in glauconitic form. This deposit is situated on the east side of Greenwater Lake on location R 526, and forms a dyke in the Huronian schists. Map No. 2 will show the situation and also a transverse section of it.

G. At the west side of Greenwater Lake half a mile west of Head Lake some similar deposits appear striking with the foliation of the Keewatin rocks nearly southwest-northeast, and are traceable for over two miles. The rock is here a peridotite partly changed into serpentine and well separated from the iron; this is principally observed at the northwest side of the hills. We have here therefore the same condition as at the east side of Greenwater Lake, that is, the cooling of the rock was comparatively slow. A large portion of the iron deposit has been cut away by icebergs, but at the foot of the hills we can easily observe how it rests against the rock, with a widening angle towards depth. The structure of this iron is crystalline, similar to that of the Atikokan; averages over 50 per cent. metallic iron and 0.15 per cent. phosphorus and carries a small percentage of sulphur.

The serpentine particles containing magnesia which are disseminated through the iron should have a purifying effect on the iron in the smelter in regard to its phosphorus, similar to the basic process. It would be interesting to find out the correctness of this hypothesis. Map 2 shows a transverse section of one of the hills. There have been no other iron ore deposits of this class discovered in this district so far, if we except the large titaniferous iron, or ilmenite deposits which exist here, but they have been and are still such terrible "scarecrows" to the iron smelter that I shall not say anything about them.

Further, there are quite a number of massive nickeliferous pyrrhotite deposits in this country "free of copper" which could be used for iron smelting. Nine years ago I made a proposition to eliminate the sulphur from these ores, use the resultant ferric and nickel oxides for making ferro-nickel, and save the sulphurous acid for any other commercial purpose: with correctly constructed roast-ovens this should be a success.

I leave now these very interesting deposits of Class 2 and pass over to "H" of Class 3.

At the northern margin of the Animikie rocks, especially in their lowest member, the chert and jasper, are found scattered over a considerable area thin horizontal layers of a very pure high-grade magnetite. These finds are remnants of ores which were once interstratified between the lowest bands of the chert, and escaped erosion and glacial action. They are seldom of great extent horizontally, or thickness vertically, resting either on the granites, gneisses or a rock of the Huronian series. On Map 2, I give an example how they occur. Now let us try to find out how this iron got into or between these chert and jasper beds, and what caused them to become magnetic. The deposition of the chert and jasper was produced by hot mineral springs, doubtless of considerable volume and of widespread extent, carrying silicate acid and some carbonate of iron in solution. These two substances were precipitated and later solidified together, that is, they not only mixed mechanically together, but also the iron seems to have partly separated from the silica and formed little " pools " of its own.

Now, it might be said that this iron had been an oxydiation product of the chert, that is, that oxygen changed the carbonate of iron of the chert into ferric oxide and the latter replaced the silica, and formed these iron layers. I doubt this as far as all these latter are concerned. If that theory would be correct in every instance, we should be able to trace this replacement from one object to another, from chert to iron, but I was unable to detect this at such places where it would have been best observable, where later oxydation and cementation processes were highly unfavorable, as for instance at the " Wigwams," three isolated cones standing high and dry overlooking the country for miles. We see here, on the precipitous rock exposures, the cherts resting on the granite to a thickness of 20 feet and more and interstratified with the magnetite; both are overlayed by a varying thickness of trap, sometimes up to over 100 feet. But the teeth of time are gnawing also on this hard material and we see iron and chert falling out of their resting-places and covering sparingly the foot of the hills. Each of them, sharply separated from the other, they do not show a trace of partial pseudomorphism, from which we could conclude whether it originated from chert or not. I will not say that there are not a few places where the magnetite seems to be derived through the alternation of the chert, that is, that ferric-oxide was produced before the trap overflow occurred and that this oxide was then also converted into magnetite; but what I am claiming with the above is that the carbonate of iron did not only exist as a mixture with the chert, but that also pure carbonate of iron deposits of a small extent were formed at the same time with the formation of the chert and jasper. We have now to answer the question, how was the carbonate of iron changed into a magnetite? Simply through the heat of the trap lava which flowed over the chert in considerable thickness, and also through its hot floor, the granite; in other words, through the heating of the iron with the exclusion of air, the carbonate was converted into a ferro ferric oxide.

We find these conditions, as I mentioned above, only at the northern margin of the chert, that is, where the slates have been thin, while towards the thicker portion of these rocks the iron retained its original state as a carbonate, that is, of course, as far as the just described phenomenon has influenced the conversion of the siderite into a magnetite. Other conditions have prevailed, but I shall speak of these another time. I have also postponed mentioning to you the occurrence of hematite ores, which doubtless exist in considerable quantities in this country, but, strange to say, nobody seems to have observed "the signs on the walls."

If this paper had not already reached too great a volume, and our hustling secretary had not been too anxious to have the manuscripts for printing in his possession as early as possible, I should have dealt with the description of all the different iron occurrences in our western districts.

Those which I have had to leave for the next meeting are the most interesting and are likely to prove for the future iron industry of Canada of the greatest importance.