## II.—The Iron Ores of Nictaux, N. S., and Notes on Steel Making in Nova Scotia. By E. Gilpin, Jr., LL.D., F. R. S. C., Inspector of Mines.

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It is commonly known that in the earlier days of the iron industry, pig iron was made by smelting iron ores in blast furnaces. The product was either melted again in foundries and run into moulds, or, as it is generally termed, used as cast iron. This every one is familiar with as the ordinary form of iron, of which a stove may be taken as a sample. Another application of the pig iron was for making wrought iron. This was effected by driving out the impurities of the pig iron by heating and oxidation, until it was practically pure and malleable. Horse shoe iron may be taken as an example of this variety. Still, another application of the pig iron was to turn it first into wrought iron, and then by restoring part of the carbon eliminated by the puddling process, to produce an iron intermediate between malleable iron and cast iron, and known as steel.

It was found at an early date that this latter product could be so manufactured as to fill as desired any grade between cast iron and malleable iron. It could be made to combine hardness, stiffness and tenacity, or on the other hand, to approximate in qualities to the very best malleable iron with certain additions of tenacity and strength. The discovery that it was possible to produce so useful a variety of iron, encouraged the best exertions of leading chemists and metallurgists. The problem was the cheap and regular production of steel in any grade required, soft or hard, for steel rails, or for those purposes requiring flexure and strength combined. With the certainty that fortunes awaited the happy discoverer of a commercially successful method of making steel, many experimenters labored for years, and under difficulties, which do not confront the metallurgists of the present day, succeeded partially in making steel, but managed with more success in designing methods for producing malleable iron by direct processes which, however, could not compete in cheapness with malleable iron made from pig iron puddled by hand.

At this stage the Bessemer process appeared, and the difficulty was solved. Steel could be made with regularity of output and uniformity of composition, and it came at once into commercial competition with wrought iron. At first many difficulties were encountered, not the least of which was the disposition to doubt that a desired standard of uniformity in tensile and other tests could be maintained, Step by step the chemist and the steel maker advanced, this difficulty was solved by an enquiry into the composition of the ores, the fuels, the re-actions in the furnace, while the practical steel maker invented the improvements required in the shape of the convertors, the machinery needed to handle it, the linings, etc. Finally, the test requirements for steel rails, girders, etc., imposed by architects and engineers, were easily and regularly met, and it was acknowledged that steel was the king of all metals. Borrowing from other elements their properties, it became hard almost as a diamond, or flexible and soft so that it could be pressed without breaking into a dish or kettle. Few people taking up a piece of steel imagine what a long history of investigation, experiment, and down-right hard inventive work it represents, probably the greatest and most important of our generation

It was found to be a *sine qua non* that good steel required as its foundation good pig iron. Pig iron that did very well for common foundry purposes, or that could be puddled into fair bar iron, would not answer for the Bessemer process. This discovery called for the best of materials. Some ores were useless, some fuels carried too much sulphur or phosphorus, etc. The limits within which fuels and ores and fluxes were suitable for the Bessemer process were soon defined exactly, and of course the composition of the pig iron to be produced for conversion into steel was defined with equal exactness. The amounts of phosphorus, sulphur, silicon, etc., allowed in the pig iron were inexorable, and iron fulfilling the conditions of purity became known as Bessemer pig. This always commands a higher price than ordinary pig iron, and at the present moment ranks next in price to pig iron made with charcoal, a very pure fuel, and the most expensive form of pig iron.

This necessity for a very pure variety of iron ore at first limited the production of Bessemer steel and kept up its price. Gradually, however, prospectors searched all parts of the earth within easy reach by water of England and Germany the early homes of this new process. It was soon found that Spain, Elba, and Algiers could be drawn upon for enormous supplies of ore of the requisite purity and cheapness. Rich ores were found on the north-west coast of England, and large steel works were started in Cumberland. Now iron ore is carried to England from Norway within the Arctic circle. Similar necessities led to the discovery of rich ores in Pennsylvania and on Lake Superior, and to the establishment of steel works at Chicago and other points in the United States.

The result of the ready supply of these cheap and pure ores, and the reduction of the Bessemer process to an exact science, was a steady course of declension in the malleable iron production, and in the production of pig iron, so far as its derivatives came into competition with steel. So noted is this in England that the output of iron ore in the Cleveland district has fallen from 6,000,000 tons to 4,000,000 tons a year. The ore of this district being of inferior quality, and capable of yielding only a pig iron, the conversion of which produced an iron incapable of competing with steel.

The effect of this cheapening of steel is most clearly shown in the case of steel rails which have replaced iron rails, and have themselves fallen in price per ton from $50 to $22.

The great advantage given by cheap water carriage and pure ores to the steel makers situated on tide water, produced a feeling almost of despair in the continental blast furnace districts, which were some distance from water carriage. They saw that their iron was being replaced by steel, and that the expense of carriage acted as a measure of protection to their more fortunately situated competitors. It looked as if the steel production of the world was to be practically limited to those countries which had the opportunity of assembling at the water edge a good and cheap local fuel and a pure water borne ore; or, to a country like the United States of America, which, possessing both these requisites, had also a cheap land and water carriage, and an almost unlimited home market.

At this point in the history of steel an unexpected and important discovery was made. It was found that under certain conditions of manipulation, including a basic lining for the converters, *i. e.*, the use of substances such as magnesia, it was possible to convert phosphorus, the great enemy of the Bessemer process, into an important adjunct in steel making. As hitherto the limit for phosphorus in Bessemer ore (.07) was measured by hundreds of one per cent., and the great difficulty was to find iron ores free from it in large enough quantities to ensure a regular and cheap supply, it is plain that when as much as three per cent. of phosphorus was permissible in the new process, a fresh field was opened up. Briefly speaking, the process consisted in the burning out of the carbon, silicon, and sulphur, by manganese and the phosphorus, the latter after discharging its kind offices practically eliminating itself.

As was to be expected, this process, known as the Thomas Gilchrist, specially recommended itself to the German steel makers who had at hand large supplies of low grade ores. Large establishments were started there and at other points on the continent, and now the Bessemer steel makers of England find their markets successfully invaded by the makers of basic steel. In spite of the experience thus gained during the past few years in England, the steel makers there, bound by prejudice, are only now awaking to the fact that they must be distanced by the continental steel makers, unless they adopt the process based on the poorer and cheaper ores. Thus the inventive faculties of two men threaten to divert a great trade, and to starve an industry in which millions are invested in England.

The extent to which the manufacture of basic steel has been carried in Germany may be gathered from the fact that in 1894 the production of pig iron there was in round numbers 5,000,000 tons, of which nearly 50 per cent. was Thomas iron. In England in 1894 the percentage was about 15. In the United States matters are much as in England, indeed the percentage of basic pig is less. Here, however, the conditions are different. The cheap supplies of pure ore available at Chicago, Cleveland, etc, from the iron mines of the Lake Superior district, and a protective tariff, have permitted an adherence to the firmly established Bessemer process But the fact remains that in the markets open to the competition of the world the cheap steel, low wages, and reasonable freights of the German steamers, combine to enable them to undersell American and English competitors.

No metallurgical process during the past thirty years has received more attention from the chemist and capitalist than the relation of phosphorus to iron and steel. Interminable researches on the part of chemists and analysts, costly experiments, in which capital has lavishly poured out its money, have combined to force from nature the secret of pure steel. As we have seen, the iron ores of the world are divided, as regards steel, into Bessemer and non-Bessemer, according to the proportions of phosphorus present.

Speaking in round numbers of the 12,000,000 tons of steel made in 1893, about 75 per cent. are made of ores that contain not more than .07 of phosphorus to the 100 parts of iron. The remaining 25 per cent. are made from ores containing from .10 to 2.50 per cent. of phosphorus.

The principle governing both processes of steel making are based on the fact, practically correct, that all the phosphorus in the ore smelted in the blast furnace goes into the pig iron. It thus happens that in the case of a Bessemer pig iron the phosphorus is a trace, while in the case of a basic pig iron it may run as high as 2.5 per cent.

Bearing these distinctions in mind, the question of the adaptability of the iron ores of any district in the Province of Nova

Scotia to steel making, by either of the above processes, may be intelligently considered.

In the Province of Nova Scotia we have entered upon the steel making era. In one sense this was the case twenty-five years ago, when cement steel was made at Londonderry from the product of a small charcoal furnace. From a practical standpoint, however, steel making may be said to have commenced when the New Glasgow Iron, Coal and Railway Company made Bessemer pig at Ferrona, in Pictou County, for conversion into steel at Trenton. The ores belonging to this company, on the East River of Pictou, produce a pig admirably suited for the Bessemer process. For more common grades the company has drawn upon Torbrook, and are preparing to import from Newfoundlaud ores which exert a softening effect on the pig iron and fit it for foundry use. Favorably situated as this company is for very pure ores, cheap and close at hand, the basic process presents few attractions. It may be predicted that when the other iron ore properties of the Pictou district become developed it will be a great steel producer, and also be in a position to supply the demand of the foundryman.

In the Nictaux district, in Annapolis County, on the contrary the conditions, so far as they are worked out, resemble rather those of Germany, and a vast series of ores are presented suitable for the basic process, in addition to some which can be graded as Bessemer.

Nictaux is the name given to a district on the south side of the Annapolis Valley, about thirty miles from Annapolis. It is traversed by the Nova Scotia Central Railway from Middleton on the Windsor Railway to Lunenburg on the Atlantic; and by the Nictaux River, which has cut deeply into the south mountain. The geological age of this iron-bearing district has been partially worked out by Sir William Dawson, who refers the iron ore rocks to the Devonian. I shall however not enlarge on this point, as Dr. A. H. MacKay has spent some time in the district, and has kindly consented to describe the geological features in detail.

The district extends from a point several miles west of the Nictaux River to the county line between Annapolis and Kings, and probably some distance further. It varies in width up to about five miles. In this section there are a number of beds of iron ore having a general north-east and south-west course. While exposures are frequent, there are undulations and fractures in the measures which render any positive correlation of the ore beds a matter of uncertainty, owing to the limited exploratory work yet effected.

The most northerly range of iron-bearing strata is represented by the bed worked at the Torbrook mine. This has been traced about 2 miles eastwardly to the county line, and for some distance to the westward. Exposures of red hematite, near Nictaux Falls, are believed to show its further passage in that direction.

South of this comes the deposit known as the "Shell Ore" bed, which was worked for several years by long trenches running on its outcrop. Its principal exposure is on the Banks farms, where it is from five to eight feet thick. This ore is highly fossiliferous, and has furnished many interesting fossils to visiting geologists

Still further south on the Canaan Mountain road, about 2 miles south-west of the Torbrook mine, are two beds of red hematite 4 to 6 feet thick. These beds, assuming a westerly course, apparently coincide with an exposure of red hematite ore reported on the southern end of the Banks farm. The further westward extension of these beds is unknown, they may in a magnetised condition be represented in the Page and Stearns beds on the west side of the Nictaux River. Here mining operations have exposed eleven beds from 2 to 10 feet in width. These beds, with others lying on the same horizon a little to the south, one of which on the river bank is about 12 feet wide, extend to the westward nearly 2 miles to the Willett property in the rear lines, where two beds, each about 5 feet thick, have been uncovered.

South of this range, on the Torbrook, other beds of magnetite and shell ore are exposed on the Armstrong and other farms, some of which reach a thickness of 20 feet. Some of these beds are stated to have been traced for a distance of six miles. Still further to the south, beyond the township line, specular ore is said to occur in a vein 6 feet wide.

While the work done in this district has shown the presence of numerous beds of iron ore, much is still needed to trace their relative positions, their continuity and their economic value. The continuous extension of all the beds in an unbroken line from end to end of the district can hardly be hoped for, as there are evident dislocations at several points, and flexures of the strata. As to the quantity of ore there can be no question. The amounts available above the water levels of the Torbrook and Nictaux Rivers must be enormous.

The question of the economic values of the ores must be the subject of extended investigation. Practical working has shown that the red hematites can furnish a foundry and forge pig The magnetites are with some exceptions too phosphoric for this purpose. The percentages of this element vary between °5 and 2.00 in the different beds. The ores are as a rule silicious, and in some cases manganiferous, but low in sulphur. They are not to be compared in purity with the magnetites of the North Mountain on the opposite side of the Annapolis Valley. Here the ores are as a rule of unusual purity, but they have not as yet been found to occur in amounts of economic value. They are presented as veins in the trappean rocks, highly crystallised and often showing banded structure, with layers or crystals of amethyst, quartz, etc.

The ores of the district run high enough in iron and phosphorus and low enough in sulphur to answer for the basic process, and their large silica contents would prove the principal obstacle to their use for this process. I believe, however, that on the continent furnace managers have been able to successfully meet this trouble when smelting for the basic process. No doubt further search will show ores running lower in silicious matter, and the large deposits of bog ore in this district can be also utilized in this connection.

To upset these drawbacks it must be remembered that the mining of these ores and their transportation would be cheaper than from almost any other iron ore district in Nova Scotia, and the preliminary outlays for machinery, drills, wire, tramways, etc., be reduced to a minimum by the facilities available for utilizing water power for generating electrical power.

The following tables of analysis of samples from the outcrops of a number of these beds, as well as from the underground workings of the Torbrook mine, will serve to give an idea of the values of these ores :—

The following analyses show the quality of the ore mined at Torbrook :

Metallic Iron....52·44, 60·72, 59·00, 61·38, 47·00, 55·74, 74·59, 11·57, 57·93, 59·86.
Silica ..........11·00, 10·28, 12·86, 26·50, 10·12, 14·97, 17·21, 5·93, trace.
Phosphorus...... 1·66, .17, trace, 1·08, trace, ·18, ·17, ·16, none.
Sulphur........None, trace, trace, trace, trace, ·23, ·08, ·09, 0·36, ·11,
Lime............ 2·70, trace, 2·16.
Magnesia ....... ·41, trace, trace.
Alumina ....... ... 5·53, trace, 3·14.

Analyses of crop sample from beds on Armstrong's and other farms :

| | Iron. | Silica. | Phosphorus. | Sulphur. | Manganese. | Titanic Acid. |
|---|---|---|---|---|---|---|
| 1.— | 54·71 | 11·56 | ·669 | ·007 | .... | .... |
| 2.— | 42·80 | 10·39 | ·396 | ·015 | ·52 | .... |
| 3.— | 54·84 | 10·87 | 1·452 | ·015 | ·41 | ·144 |
| 4.— | 53·10 | 14·16 | ·704 | ·025 | ·24 | .... |
| 5.— | 55·40 | 20·35 | 1·037 | ·114 | ·26 | .... |
| 6.— | 54·28 | 7·97 | ·53 | ·028 | ·28 | .... |
| 7.— | 52·40 | 9.41 | 1·861 | ·030 | ·23 | .... |

Miscellaneous analyses of ores in the Cleveland and Torbrook districts :

*Magnetites.*

| | No. 1. | No. 2. | No. 3. | No. 4. |
|---|---|---|---|---|
| Metallic Iron...... | 54·22 | 59·11 | 53·14 | 54·96 |
| Silica ............ | 14·97 | 11·64 | .... | 11·12 |
| Sulphur .......... | ·069 | ·09 | .... | trace. |
| Phosphorus ........ | ·36 | ·17 | ·172 | ·192 |
| Alumina.......... | 5·53 | .... | .... | 3·14 |
| Lime .............. | 2·70 | .... | .... | 5·88 |
| Magnesia .......... | ·41 | .... | .... | 2·01 |
| Manganese ........ | ·86 | .... | .... | .... |

*Red Hematite.*

| | | | |
|---|---|---|---|
| Metallic Iron .............. | 58·05 | 57·93 | 18·47 |
| Silica...................... | .... | 17·21 | 33·50 |
| Sulphur .................... | .... | ·03 | .... |
| Phosphorus ................. | ·193 | ·16 | .... |
| Alumina .................... | .... | .... | .... |
| Lime ....................... | .... | .... | 3·00 |
| Magnesia ................... | .... | .... | .... |
| Manganese .................. | .... | .... | 9·80 |

*Mining development of the Nictaux distrtct.*

The existence of iron ore was known here at an early date in the history of Annapolis County. Haliburton, writing in 1829, speaks of the first attempt as "an ill directed effort made many years ago." I am unable to give any particulars of this operation, but presume it was directed to the manufacture of wrought iron by a forge process. The hard compact ores of the district were not suited to this primitive method.

Gesner gives an interesting account of the iron ore deposits of Annapolis County, and refers to the bed of shell ore on the Banks farm as 6 feet 6 inches wide. In 1856 another attempt was made and a furnace built at the falls. The iron produced was largely from the shell bed, and is stated to have been of inferior quality. Harrington gives some details of these furnaces in his report on Canadian Iron Ores, 1874. The fuel used was charcoal, readily furnished by the great forests to the south. Some years later the ores of the district again received attention during the construction of the Nictaux and Atlantic Railway. The Messrs. Page and Stearns opened a number of beds on the west bank of the Nictaux River. A few experimental cargoes were shipped, and some was found to be of very good quality. Delays in the building of the railway led to the closing of the mines. These beds were magnetite, massive and fine grained.

A few years ago Mr. R. G. Leckie secured the outcrop of a bed of excellent red hematite at Torbrook, about three miles east of Nictaux, which has been worked since by the Torbrook Iron Co. The bed runs about north-east and south-west, with a steep dip to the north, and is enclosed in soft slates. The ore is massive and fine grained, and as shown by analysis, an excellent foundry material, The mine is well equipped and opened for a length of about 1,500 feet, and to a depth of about 200 feet, the bed being from five to seven feet thick. Up to date about 80,000 tons have been mined here, which has been used by the Ferrona and Londonderry furnaces as a mixture with their harder ores.

Captain Hall, of Middleton, has for several years paid much attention to the ore beds, and owns a number of properties covering large and valuable deposits.