C H A P T E R II

DATA ON IRON ORES

The main purpose of this report is the presentation of data on the iron deposits of Nova Scotia. Data on iron ores in general will assist in any assessment of the economic value of any particular deposit described in the following chapter. There are only a few industrially important minerals of iron, although several hundred minerals contain iron. In most iron ore deposits, magnetite, hematite, siderite, limonite are the major iron minerals. Marketable iron ores are derived from oxide, carbonate or sulphide deposits.

SOURCES OF METALLIC IRON

MAGNETITE

Composition Fe_3O_4 (iron content 72.4 per cent); color is iron-black, ore is strongly magnetic; specific gravity is 5.17-5.18. It has octahedral parting due to twinning, which is often well developed. Magnetite occurs often as veins and stringers in igneous rocks; disseminated in rocks to form bodies of low-grade ore; as replacement in sedimentary and metamorphic rocks and as banded layers in metamorphic and igneous rocks. Magnetite has never been known to occur pure in masses of more than a few tons, or of very high grade in deposits yielding more than a few thousand tons.

HEMATITE

Composition Fe_2O_3 (iron content 70 per cent). It is by far the most important iron mineral in the iron deposits of Nova Scotia. Hematite has a metallic to earthy lustre, and the color is steel grey to black, reddish black and red.

Varieties are specular iron which occurs in very brilliant plates or crystals; red ochre, an earthy, more or less impure material; and martite, pseudomorphs after magnetite.

Hematite occurs mainly in bedded deposits in sedimentary rocks and is usually associated with other iron minerals. The iron content of the hematite deposits in Nova Scotia varies from 42 per cent to nearly 66 per cent in a deposit at Barachois, Cape Breton Island.

LIMONITE (GOETHITE)

Composition $(2Fe_2O_3, 3H_2O)$ (iron content 62 per cent). Essentially a superficial weathering product of hematite and carbonate $(FeCO_3)$. Goethite (Fe_2O_3, H_2O) is very similar in composition to limonite, but is distinguished from it by being crystalline. Limonite takes a great variety of forms, colors and degrees

of hardness and compactness; botryoidal, stalactitic, massive or specular in form and many shades of yellow and brown to almost black in color. The iron content of the limonite mined from the various deposits in Nova Scotia is approximately 45 per cent.

SIDERITE

Composition $FeCO_3$ (iron content 48.2 per cent). Color may be brown or grey, rarely greenish, reddish, yellowish or black. It tarnishes reddish brown to brownish black. Siderite veins occur in Pictou County and in the Londonderry iron deposit in association with ankerite.

ANKERITE

Composition $Ca,Fe,Mg(CO_3)_2$. Ankerite is usually mixed mechanically with siderite, hematite and limonite. The largest bodies of ankerite are in the London-derry area, Colchester County and average less than 10 per cent metallic iron. Since ankerite contains iron, lime and magnesia, it is useful as a flux and at the same time contributes to the iron content of the furnace charge.

CHAMOSITE

Chamosite is a hydrated ferrous aluminum silicate, greenish in color. It occurs associated with hematite in narrow beds at Piedmont, Pictou County, and to a lesser extent in the iron ores in the Torbrook-Nictaux area. In most occurrences chamosite occurs as concentric layers surrounding a nucleus composed of quartz, a shell fragment or a small area of hematite. The iron (Fe) content of chamosite is approx-imately 16 per cent.

IMPURITIES IN IRON ORE

The value of an iron ore is not entirely determined by the iron content. While the iron content of an ore is important, it is not necessarily the most critical constituent, as heavy penalties are imposed if the ore contains certain undesirable impurities. The chemical constituents of minerals associated with iron-ore minerals are commonly designated as oxides - silica, alumina, lime and magnesia; or as elements - sulphur, phosphorus, manganese, titanium, chromium and nickel. Some of these constituents, which in general are referred to as impurities are harmful, whereas others are beneficial. The main impurities in iron ores and their action in the furnace are described below:

SILICA

Silica acts as an acid in the blast furnace and must be fluxed with a base, such as lime or magnesia. High silica ores are uneconomical to use in ordinary blast furnaces by reason of the high fuel consumption caused by the excessive amount of slag obtained. Such ores require large quantities of lime to neutralize the silica. Such low iron-high silica ores should therefore be beneficiated prior to smelting or sweetened in smelting with high grade ore or scrap iron.

Steel plants prefer an iron ore running 6 to 8 per cent silica, but ores are accepted that carry up to about 12 per cent silica. There is no premium paid for iron ore containing low silica. About 2 pounds of limestone ($CaCO_3$) is needed to flux each pound of silica. Of course, a low silica ore is more valuable than one with high silica, as normally the iron content will be higher and the producer is not required to pay shipping charges on valueless silica.

PHOSPHORUS

Phosphorus present in the iron ores cannot be removed in the slag and nearly all goes into the pig iron on smelting and must be removed when it is converted into steel. Steel with a high phosphorus content tends to be brittle and cracks on rolling. High phosphorus pig iron is used in limited amounts in making complicated castings where high fluidity is needed and great strength is not necessary. The amount of phosphorus in the pig iron then ultimately determines the process to be used in the manufacture of steel. The figures given below show the limits of allowable phosphorus in pig iron for the various steel manufacturing processes:

> Acid open-hearth - less than 0.05 per cent
> Acid Bessemer - less than 0.1 per cent
> Basic open-hearth - not over 1.5 per cent
> Basic Bessemer - at least 1.5 per cent and preferably over
>   2 per cent
> Foundry iron - wide range according to the ultimate use
>   intended for the product

SULPHUR

Sulphur, which is usually derived from sulphide bearing minerals, is undesirable and high sulphur ores are penalized. No premium is normally paid for low-sulphur ores, but the percentage should not exceed 0.1 per cent. A small percentage of sulphur in a blast furnace charge is eliminated with the gas, but the rest is divided between the slag and the pig iron.

The sulphur content of the iron ores of Nova Scotia varies between .010 per cent and 6.18 per cent. It is more abundant in the specular hematite deposits, than in magnetite and bedded hematite. Very little sulphur occurs in the limonite

deposits of Nova Scotia.

TITANIUM

Titanium is frequently found associated with magnetite ores and is particularly undesirable. Iron ores with 0.1 per cent titanium are difficult to market. It is not possible economically to separate the titanium by milling because of the ultimate association and intergrowth of the minerals in the ore. Titanium is objected to by users of iron ores because it is said to make a pasty slag and may eventually choke the furnace.

The iron ores of Nova Scotia contain very little titanium. It is present in some of the magnetite from the Triassic basalt and occasionally associated with the magnetic hematites in the Torbrook area. Titanium was not determined in many of the analyses available.

MANGANESE

Some manganese is usually associated with iron ores, especially in the hematite and limonite types. Manganese bearing iron ore is desirable in the basic open-hearth process for deoxidation and sulphur removal. If the manganese content of the iron ore is sufficiently high, spiegel iron with 10 to 30 per cent manganese can be produced in the blast furnace. The allowable manganese content of pig iron for the manufacture of steel varies between 0.5 per cent and 2.5 per cent. It is very difficult to alter the percentage of manganese in the crude ore by beneficiation as the properties of the iron and manganese minerals are similar. Manganese content above 2 per cent is generally paid for at the same rate as is paid per unit of iron content.

The limonite and hematite, especially along the Windsor-Horton contact averages 4 per cent manganese and at one point 24.7 per cent. The Triassic magnetite and the Torbrook magnetite and hematite have very little manganese and that does not occur persistently.

ALUMINA

Some alumina, occurring chiefly as kaolinite, is present in many iron ores. If it occurs in excess of 5 per cent, there may be some difficulty in finding a market and a penalty is imposed. As the alumina content increases, the iron content decreases and the ore becomes waste material.

Alumina is rarely present in the Nova Scotia iron occurrences in such quantities as to be harmful, except where the iron minerals are mixed with argillaceous country rock. All of the analyses available from various iron occurrences in Nova Scotia indicate an alumina content of less than 5 per cent.

LIME AND MAGNESIA

Calcium and magnesium occur in iron ores as carbonates and silicates. They are considered desirable impurities in ore to neutralize the silica and form slag. If appreciable quantities of lime and magnesia are present, a higher silica content can be used. About 2 pounds of lime are necessary in the blast furnace to flux one pound of silica and more coke is required when ores of high silica and low iron content are used.

ARSENIC

Arsenic is reduced in the furnace and practically all of it remains in the metal. It is objectionable in steels used for canning foods because of its poisonous aspect.

OTHER MINOR ELEMENTS

The occurrence in an iron ore of copper, zinc and nickel is undesirable as these elements accumulate in the hot metal and effect iron and steel making processes. The combined amounts of copper, lead, zinc, arsenic, chromium, vanadium and nickel should not exceed 0.05 per cent.

PHYSICAL PROPERTIES OF IRON ORE

In addition to the mineralogical and chemical composition of the iron ore, it is necessary to mention the following physical properties:

MOISTURE

The moisture content varies from around 1 per cent for hard dense hematite and magnetite to more than 20 per cent for soft limonite ores. The moisture content in an ore should not exceed 10 per cent.

DENSITY

It is necessary to know the density of the ore in order to establish tonnage estimates. The variation in the porosity of the iron ore accounts largely for the difference in density. Lean, cherty, waste rocks with less than 40 per cent iron in some cases, have a higher density than ore containing 60 per cent iron.

HARDNESS AND STRUCTURE

Magnetite ores are usually hard while carbonate ores vary from relatively hard to soft. Hematite and limonite ores range from hard, dense varieties to soft and earthy types. The structure of an iron ore refers to the proportion of fine and coarse fragments. If the iron ore contains more than 15 per cent fines, it is not acceptable by the steel plants.

LOSS ON IGNITION

In the chemical analyses of iron ores, volatile material such as carbon dioxide and chemically combined water are reported as "loss on ignition". If the iron ore carries a considerable amount of carbonates and hydrated iron oxides, the loss on ignition may be considerable, thus reducing the iron content.

CLASSIFICATION OF IRON ORES

For commercial purposes, iron ore is classified according to chemical composition and physical character. If the material as mined meets market specifications for composition (51.50 to 65 per cent iron) it is classed as direct-shipping ore; that is, it requires no treatment before smelting. Material of direct-shipping quality usually contains up to 12 per cent silica and 0.045 per cent phosphorus, about 1.5 per cent alumina, variable amounts of manganese and small amounts of calcium and magnesium.

The greater part of the iron ore smelted requires concentration of the iron and removal of undesirable constituents before they can be utilized. In some cases a simple washing process is used to remove the fines, which are the lean parts of the ore, in order to up-grade it to direct-shipping specifications.

By-product iron ores are those that are derived from the mining and treatment of an ore from which some other valuable constituent is also recovered. Iron in the form of pyrite, pyrrhotite and magnetite is a major constituent in many sulphide deposits mined for nickel, copper, base metals and gold. Considerable iron is being recovered from the sulphide deposits at Noranda, Quebec, in the Sudbury area, Ontario, and from pyrrhotite tailings at Kimberley, British Columbia.

Further classification as to chemical composition is also necessary. Ores with a phosphorus content not exceeding .045 per cent are known as Bessemer ores, and if the content is over .045 per cent but not greater than .180 per cent the term non-Bessemer ore is used. If the phosphorus exceeds that amount the ore is classified as high-phosphorus ore.

It is difficult to draw a line between direct-shipping ores and those of lower classification, because practically all ores are now upgraded ar beneficiated in some way before shipping. As structure is a very important aspect of iron ore, the size of the ore pieces must be neither too large nor too small ta be treated efficiently in

the blast furnace.

The physical character of iron ore is the basis for a two-fold classification. Lump or hard ore is very compact and coherent material and is especially desirable for use in open-hearth furnaces. Soft ore is porous, granular and earthy, only moderately coherent and breaks down easily when handled. A high percentage of the ore passes the quarter-inch diameter screen and only a small amount can be used directly in the furnace without choking gas circulation.

TYPES OF IRON ORE DEPOSITS IN NOVA SCOTIA

The iron ore deposits of Nova Scotia have been formed by a variety of geologic processes and combinations of processes, but three general types of deposits are most important. These ore bedded, replacement veins and residual deposits. Minor amounts of bog iron ores occur at several locations in Nova Scotia.

Bedded iron deposits are sedimentary layers that accumulated by precipitation of iron compounds in bodies of water. The deposition was in bogs, lakes or seas, and the iron deposits are associated with the normal sequence of strata formed in these environments. Bedded iron deposits are generally very extensive, but only a part of the material is ore. The hematite bearing bedded deposits in Nova Scotia are marine sedimentary rocks which, except for weathering along the outcrop, have remained practically unaltered since deposition. The ore beds are commonly interbedded shelf type sediments and with dark green to black shale, sandstone and argillite. This type of iron formation is most extensively developed in lower Palaeozoic rocks and consists of beds of red hematite-chamosite oolites, formed around fossil fragments or clastic debris.

Iron deposits of the replacement and vein type are massive or tabular bodies of iron ore minerals that have taken the place of pre-existing rock forming minerals or have filled voids in the rock, especially openings along fractures. Constituents forming the iron ore minerals were presumably derived from magmatic sources in the hydrothermal variety of replacement and vein deposits and from products of rock weathering transported by ground water in the surficial variety. The shape, size and distribution of the replacement type are controlled mainly by structural features, and only a few are large enough to be of economic importance. Iron minerals, probably of replacement origin, are disseminated along shear zones or fracture and joint systems.

Residual iron deposits have formed by decomposition of a variety of rocks whose original iron content has been increased by removal of nonferrous constituents. The deposits are limonite, hematite and goethite that were originally in the rock or were formed from iron-bearing carbonates or silicates. The best example of residual deposits are in the Londonderry area of Colchester County. The ore consists of limonite (goethite) and hematite and occurs in ferruginuous carbonate rocks (ankerite) containing 10 to 12 per cent iron. The residual iron accumulated in lenses and pockets as a result of weathering processes.

Most bog iron deposits are small and of minor importance. Included in this

group is precipitated iron usually goethite (limonite) but occasionally some siderite. Organic debris and carbonaceous material may be replaced by ferric oxide compounds and in some bogs by siderite. Manganese oxides may be present and all gradations can occur from bog iron to bog manganese deposits. Bog iron deposits may indicate other types of iron occurrences in an area, such as carbonate beds or sulphide deposits.

EVALUATION OF IRON ORES

Many factors have to be considered before exploiting an iron deposit with the idea of establishing an iron ore industry. The chief factors are: (a) ore grade; (b) amenability to concentration; (c) location with respect to transportation and (d) the size of the deposit.

Preferred ore used now contains 60 to 66 per cent iron, less than 6 per cent silica, less than one per cent lime, magnesia or alumina, and is very low in phosphorus and sulphur. The importance of using high grade ore in blast furnace operations make it profitable to concentrate ores containing as much as 60 per cent iron.

In order to determine if the iron ore is amenable to concentration and treatment, many tests are necessary. A mineralogical description of the ore and a geological description of the deposit is essential. Without knowing the type of mineral intergrowth and the grain size, texture and mineralogy of the ore proper procedures cannot be selected. Coarse-grained ores are easier to concentrate than fine-grained ores provided the elements present are in separate grains. If the iron ore can be separated from the gangue without fine-grinding, concentration of the iron can be achieved by several methods. Ores composed of mixtures of iron oxides, quartz, and iron silicate or carbonate minerals are difficult to concentrate. It may be impossible to liberate their mineral components even with very fine-grinding.

In recent years steel mills have been built in populated areas where the steel is sold and used. More efficient transportation and the handling of the raw material make it less expensive to move the coal, limestone and ore to areas of steel consumption than to transport the steel products to markets. The iron deposits close to steel plants may not be able to supply ore requirements and the quality may be unsuitable for modern steel making processes. To satisfy the markets for high grade iron ore, deposits are being worked in distant areas.

For economic operation, large deposits of uniform composition must be available. To be of economic importance at least 20,000,000 tons with 50 per cent iron content, if not direct-shipping ore, must be in sight.

IRON ORE PRODUCTION IN NOVA SCOTIA

(1886-1913)

886 .... 44,338 tons	1900 .... 18,940 tons
887 .... 43,532 tons	1901 .... 18,619 tons
888 .... 42,611 tons	1902 .... 16,172 tons
889 .... 54,161 tons	1903 .... 40,335 tons
890 .... 49,206 tons	1904 .... 61,293 tons
891 .... 53,649 tons	1905 .... 84,952 tons
892 .... 78,258 tons	1906 .... 97,820 tons
893 .... 102,201 tons	1907 .... 89,839 tons
894 .... 89,379 tons	1908 .... 11,802 tons
895 .... 83,792 tons	1910 .... 18,134 tons
896 .... 58,810 tons	1911 .... 22 tons
897 .... 23,400 tons	1912 .... 30,857 tons
898 .... 19,079 tons	1913 .... 20,436 tons
899 .... 28,000 tons	