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PREPARED UNDER THE DIRECTION OF
R. C. ALLEN
DIRECTOR, MICHIGAN GEOLOGICAL AND BIOLOGICAL SURVEY

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THE IRON MINING INDUSTRY OF MICHIGAN.

BY R. C. ALLEN.

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CHAPTER I.

IMPORTANCE OF THE INDUSTRY.

For nearly a half century prior to 1901 Michigan held first place in production of iron ore. In this year and annually to the present time the production from the great Mesabi range of Minnesota has over-shadowed the production of all other iron ranges and this range is now sending out more than two-thirds of the tonnage annually mined in the entire Lake Superior region and one-half of the total production of the United States. Notwithstanding the overwhelming magnitude of the Mesabi range production in recent years Michigan at the close of 1910 had shipped nearly half (221,122,495 tons) of the total tonnage mined in the Lake Superior region and about one-fourth of the entire tonnage mined in the United States in all preceding time. If these comparisons were expressed in weight of metallic iron Michigan's proportion of the total would be still greater.

PERMANENCY OF THE IRON MINING INDUSTRY.

The backward view is eminently satisfactory but what of the future? A recent estimate (1911) by J. E. Finlay for the Michigan State Tax Commission, places the Michigan iron ore reserves in sight at 196,354,883 tons, an amount which is almost equal to the total shipments to 1911. This estimate does not include low grade material which will be salable at some future time, but iron ore of salable grade under 1911 conditions. This estimate supports the contention that shipments are on the average annually exceeded by developed new tonnage to the end that reserves increase more rapidly then shipments. There is no good reason to believe that reverse conditions will begin to operate in Michigan in the immediate future. Michigan's supply of iron ore is of course exhaustible, but relatively the supply is a permanent one. No one, no matter what completeness of information he may have at his command, would care to set the date when iron mining on a large scale in Michigan will cease. There is more high grade ore in sight today than ever before, almost as much as has been extracted in some sixty-five years of continuous mining. The low grade ores have riot been touched. Of these the supply is enormous. In our present state of knowledge it is quite useless to speculate on the grand total of available iron ore. All that can be said is that the end of iron mining in Michigan is so far removed that speculations regarding the date of its appearance have no present value or interest.

THE MICHIGAN IRON FORMATIONS.

The names of the copper bearing and iron bearing formations and their age relationships are given below.

Algonkian	Keweenawan.		Copper on Kewenaw Point and in Ontonagon Co. Series.
	Huronian Series	Upper—	Iron in Ironwood formation of the Gogebic range. Iron in Vulcan formation of Iron River. Crystal Falls, and Menominee districts, and Bi iki iron bearing member of Marquette and Gwinn districts.
		Middle—	Iron in Negaunee formation of Marquette and Gwinn districts.
		Lower—	
Archean	Keewatin Series.		Iron bearing formations reported near Marenisco.
	Laurentian Series.		

The entire iron ore production of Michigan has come from the Upper and Middle Huronian series. The Middle Huronian is not known in the Lake Superior region outside of Michigan and is productive only in the Negaunee formation of the Marquette district. It has produced over forty per cent of the total output of the state.

Character of the Iron Formations: The iron formations, in which the iron ore bodies are found are sedimentary rocks composed, in an altered condition, chiefly of silica in the form of chert and quartz, and the iron bearing minerals, ferrous carbonate (siderite), ferrous silicate (greenalite) and iron oxide (mainly hematite). Oxidation has transformed most of the ferrous iron contents to iron oxide in the exposed parts of the formations producing *ferruginous cherts* ("soft ore jasper") *ferrouginous slates* and by further metamorphism (anamorphism) *jaspilites* ("hard ore jasper"). If oxidation is complete and the silica content sufficiently reduced by leaching, ore bodies result.

Relations to Other Formations: The iron formations are inter-bedded with other sedimentary rocks such as slate, quartzite and dolomite and in some places with igneous rocks of volcanic origin. In some areas they are cut by dikes and irregular masses of younger intrusive igneous rocks, notably in the Gogebic and Marquette districts.

Thickness of the Iron Formations: The iron bearing beds vary greatly in thickness in the different iron ranges. In the Gogebic district the maximum thickness is 800 to 1,000 feet, in the Marquette district from 1,000 to possibly 1,500 feet in the Iron River and Crystal Falls districts not more than 350 feet to 400 feet, and in the Menominee district the combined thickness of the two productive beds varies on the average between 300 feet and 400 feet.

Deformation and Alteration of the Iron Formation: These rocks were deposited in about flat lying or horizontal position and were subsequently folded by compressive earth movements into synclines (troughs) and anticlines (arches). During deformation the iron formations were not only folded but fractured, and along many of these fractures faults or displacements occurred. Deformation was mainly accomplished while the iron bearing beds were buried beneath overlying formations but erosion has since removed the overlying rocks in those areas where the iron formations are now exposed at the surface.

Formation of the ore bodies: The ore bodies are concentrations of iron oxide in exposed parts of the richer layers of the iron formation. They are further very largely limited in occurrence to places where structural conditions combine with other factors to render the agents of alteration exceptionally effective. The main agent of alteration is oxygenated and carbonated meteoric water. The waters descend from the surface oxidizing the ferrous carbonate and silicate to ferric oxide and leaching out the silica. Those parts of the iron formation most happily situated to receive a vigorous circulation of oxidized and carbonated waters are more apt to carry ore bodies than parts not so situated. Concentration of downward moving meteoric waters is favorably influenced by certain structural conditions such as (1) the occurrence of impervious foot walls of slate or other rocks, (2) pitching troughs with impervious basements, (3) an inclined position of the iron formation, (4) a brecciated or porous condition of the iron formation, (5) a large area of the iron formation exposed at the surface. Ferruginous chert and ferruginous slate are iron formation rocks which represent a part way stage between the unaltered phase and iron ore. In them the original ferrous carbonate and ferrous silicate minerals are partly or wholly oxidized to ferric oxide but the silica has not been removed. Rocks thus altered make up the great bulk of the iron formation.

Depth to which Iron Ore Occurs: Nearly all of the ore bodies are exposed at the rock surface. Those deposits which are not exposed at the rock surface are connected with this surface by ferruginous chert or slate, that is to say, by rocks which have been altered by processes which if completed would result in ore concentration. Ore deposits may be expected to occur to depths to which an active circulation of oxidizing waters has penetrated. Obviously such depths will depend on factors of uncertain character which vary widely in different localities. For these reasons speculation as to the maximum depth at which ore will ultimately be found is hazardous to say the least. The Newport mine at Ironwood has developed a large body of high grade ore under 2,000 feet in depth. A greater depth (2,200 feet) is attained by the ores of the Champion mine in the Marquette district. Other mines are approaching this depth. Deep drilling is meeting with encouraging results in many explorations. The ultimate maximum depth at which iron ores may be found and from which they may be profitably mined has not been attained.

THE CHARACTER OF MICHIGAN IRON ORES.

The great bulk of Michigan iron ore is hematite with some limonite and a small amount of magnetite. In statistical tables nearly all Michigan ores are graded as hematite. The textures vary from soft, granular, and powdery to hard, specular, and schistose. The lowest grade of ore shipped from Michigan mines has averaged about 40% metallic iron. The annual shipments from Michigan mines vary mainly between 50% and 60% metallic iron. For the chemical composition of Michigan ores for 1910 see statistical tables.

CHAPTER II. IMPORTANT FEATURES OF THE IRON MINING INDUSTRY.

The Geological Survey is often asked for information relative to particular features of the, iron mining industry. Naturally, these inquiries come not so frequently from those connected with the industry as from other sources, including land owners, legislators, publishers, etc., both in and out of the state. In the following pages is discussed in an elementary way some of the more important factors in the business of mining and marketing iron ore, including (1) exploration, (2) royalties, values and ownerships, (3) prices and price determinations, (4) sampling and analyses, and (5) transportation.

EXPLORATION FOR IRON ORE.

In the early days on the Michigan ranges prospecting was confined to a search for exposures of iron ore. It was not long in the early history of each range before the more promising exposures of ores were located and thereafter further discoveries resulted only from underground exploration, either projected from the workings of the mines or conducted in new ground by test pitting and drilling. In order to eliminate barren ground it was found advantageous to indicate on maps or plats the known occurrences of-iron formation, thus initiating the construction of geological maps. The early prospectors were beset with the difficulties inherent in a wooded country with few or no roads. Furthermore they had to deal with complex geological structures of the rocks, and did not have the aid furnished to the modern explorer through the publication of geologic maps and volumes of literature, the product of many years of experience and study by miners, geologists and engineers. In fact the oft repeated sayings of the Cornish miner "where it is there it is," and "where there is some there is more" well illustrate the status of knowledge of the early explorers for iron ore.

Through study and experience the geologic structure of the rocks and the conditions of ore occurrences became increasingly better understood and has had its effect in better and more intelligently directed exploration. With the discovery of each successive new range there has, however, always been a tendency for the explorer to assume that geologic conditions on the new range were analagous to those on the older range with which he was more particularly familiar. These assumptions, when strongly held, have proven more of a handicap than a help for the different ranges are unlike in succession and structure of the rocks and the most successful methods of exploration take this fact into account. The inability to quickly apprehend new or modified conditions and to meet them with a corresponding change in procedure in exploration, i. e., and inelasticity of thought and method, is less common among explorers now than it was a few years ago.

The methods of modern exploration for iron ore may best be illustrated by an outline of procedure in a suppositions case. Suppose a mining company feels the need of increasing its ore reserves by exploration in new territory. This is the condition generally obtaining in Michigan for the strength of a mining company and its continued existence depend on the opening of new reserves to take place of those which become exhausted. Those companies which are both miners and steel and iron makers find it expedient not only to maintain a large reserve of minable ore but reserves of different grades of ore for use in properly mixing furnace charges.

It may be taken for granted that the company is able to use discriminating judgment in selection of lands to explore. The larger companies maintain a force of engineers and geologists whose business it is to keep well abreast of the developments in geology and mining throughout the ranges in which the company operates.

If the lands which it is desired to explore are not owned by the company they may be obtained (1) by purchase or (2) by lease. Transfers to title of minerals in iron bearing lands on developed Michigan ranges are not common, the owners preferring to retain title as a source of income under lease. An option to explore with privilege of lease at or before the expiration of the option is practically always preliminary to a lease on undeveloped lands. The terms of the option vary, but usually contain the following major stipulations: (1) The mining company is given a certain stated length of time to explore. The owner may demand and in some cases receive a cash bonus for the option, the amount of which is conditioned on the strength of the probability of ore occurrence, etc., and may, under certain conditions, agree to an extension of the option period on request of the company. The option commonly obligates the company to make a stated minimum expenditure for exploration, to do a certain number of feet of drilling or to work continuously during the life of the option. (2) The terms of lease which may be exercised or rejected by the company are stated in the option. They include (a) stipulation of the *royalty*. The fee owner usually receives a *minimum royalty* which is a lump sum to be paid annually for the privilege of holding the lease and a per ton royalty on shipments from the property. The amount of the latter varies in different districts and localities and for different trades of ore. It may be a flat or a graded rate per ton, a certain percentage of the sale price, or under certain conditions a minimum flat or graded rate plus a premium based on the sale price. The per ton royalties are usually credited against the minimum royalties and if the former totals less than the minimum, the difference is paid. (b) The company exercising lease is usually obligated to pay taxes. (c) In lieu of a low minimum royalty there is sometimes a provision for continuous operation of the property. Under a low minimum royalty a company may find it expedient not to operate but to hold the ore in reserve. Many other items which are not here considered are included in the average lease.

Having settled the terms of the option and lease the company is ready to begin exploration. The property is surveyed, sometimes both topographically and geologically, and the engineers correlate all available geologic data having a bearing on the method to be followed. The first holes are "spotted" and the drilling begins

The business of *mining* and *exploration* have in recent years become differentiated. With the increasing use of the drill companies have been formed who conduct purely a drilling business. There are something like 400 drills in more or less continuous operation in the Lake Superior country giving employment to about 1400 to 1,500 men. Some of these companies are large operators and employ well trained engineers and geologists to conduct the exploratory operations. These companies are equipped to handle not only the mechanical but the scientific work of exploration charging only the "going" rates for drilling but using their superior organizations as a main factor in competition for business. In most cases the mining companies desire to handle the scientific end of the exploratory work but there are increasing instances of the assumption under contract by the drilling company of the full responsibility of conducting thorough and adequate exploration as great importance attaches to the results of drilling operations, the business demands in its employ men of the highest integrity.

We may suppose that the company in this case contracts with a drilling concern for a certain minimum number of feet of drilling. For vertical holes the churn drill may be used but in any case it will be less satisfactory than the diamond drill. The latter preserves a core of rock which is useful to the engineer or geologist in charge for determining structure and succession of the strata which has a most important bearing on the location of ore bodies. Great care is used to obtain and preserve the drill cores. During the progress of drilling the samples are carefully examined and identified. Each hole is platted, often in such a way that it may be considered with others in three dimensions. Geologic sections are drawn from the acquired data and used to determine position and angle of successive holes. If ore is encountered both core and sludge are sampled for determination of iron and phosphorous content.

After the ore has been found drilling continues until something is known regarding the size, shape and quality of the deposit. The subsequent initial expenditure for mine equipment is determined most largely by the character of this information.

In general the deposits in Michigan ranges are of a shape and structure so complex that the drilling must be supplemented by underground work. Relatively little drilling is done on the Gogebic range where the portion of the iron formation at the surface is accurately known. On the other hand in drift covered areas of complex structure, like the Iron River district, the iron formation must first be located by the drill preliminary to its exploration for ore deposits. Where exploration by drilling is attempted on land under option the results are usually sufficient to determine the advisability of exercising or abandoning the lease. However, there are many producing mines on lands that have been repeatedly explored and abandoned by different concerns, which serves to illustrate the fact that conditions are often such as to baffle the skill of the best equipped explorers. The element of luck still plays an important role in exploratory operations. There are comparatively few iron ore deposits in Michigan whose character and size were fully predetermined by drilling. On the Mesabi range of Minnesota the reverse is probably true.

In the case under consideration we may suppose that the results of the drilling are sufficiently encouraging to justify the exercise of the lease. The next step is the sinking of a shaft and the cutting

of underground openings, involving installation of pumping and hoisting machinery. At every step the structure of the iron formation and ore body is studied and platted until the probable size and character of the deposit is disclosed. When this information is completed or well advanced the plan of the mine is laid out and the mining methods best adapted to the conditions is determined by competent engineers. The mine is now rapidly brought to the producing stage. In most cases it is necessary to continue exploration throughout the life of the mine for in perhaps the majority of Michigan iron mines the conditions found on opening one level do not necessarily imply that the same or similar conditions will be found on other levels. The cost of exploration forms a continuous, though fluctuating charge against the cost of the ore.

ROYALTIES.

The term *royalty* refers to payment by mining companies for the ore in properties which they operate but in which they own a part or none of the mineral values. The royalty is paid per ton of ore shipped and may be a flat or a graded rate or a combination of the two. The sum paid for the privilege of holding the lease is called the *minimum royalty*. The per ton royalty is commonly charged against the minimum.

ROYALTIES PAID BY MICHIGAN IRON MINES, 1906-1910, INCLUSIVE.[1]

Range.	No. of mines producing in 1906-1911.	No. of shipping mines paying royalties.	Average royalties 1906-1911.			
			High.	Low.	Average per mine.	Average per ton.
Gogebic	14	12	\$0.82	\$0.226	\$0.405	\$0.388
Iron River	11	11	.62	.11	.2107	.209
Crystal Falls	14	13	.50	.13	.268	.262
Menominee, including Metropolitan and Calumet	12	12	.38	.05	.211	.242
Marquette	27	12	.57	.10	.2864	.331
Gwinn	4	4	.57	.20	.307	.323
	82	64				

[1]Compiled from "Appraisal of the Mining Properties of Michigan" by J. R. Finlay. Report of the Board of State Tax Commissioners, 1911.

It may occasion surprise to many to learn that more than three quarters of the Michigan iron mines are not owned by the operating companies. For the producing mines in the period 1906-1910 inclusive the figure is 78+%. If the Marquette range is excluded the percentage is 95 which about represents the present status of this factor in the iron mining business. The fees in most of the non royalty paying mines on the Marquette range were acquired long ago. There are few recent transfers of title to mineral fees in undeveloped iron range lands mainly because of the uncertainty of values. Both owners and miners prefer to deal with these lands under the leasing system.

Royalties which were actually paid by Michigan mines in 1905-1910 range from 82 cents to 5 cents per ton. The highest average per ton royalties are paid on the Gogebic range, then follows in decreasing order the Marquette, Gwinn, Crystal Falls, Menominee, and Iron River districts.

VALUES.

The royalty is the *sale price* of a ton of ore in the ground and is therefore in a sense the value of the unmined ore. Royalties are usually stipulated in options to explore with privilege of lease in undeveloped land in advance of the actual exploration. The results of the exploration determines whether the ore was sold by the owner at a high or low price. J. E. Finlay determined the average value of developed but unmined Michigan ore at 61 cents per ton in 1911. This is about double the average royalty for the whole state.

There is given below a summary statement of the ore reserves, total value, and equalized assessed value, for the state for 1911 compared with Minnesota for 1910. The approximate value per ton of Michigan iron ore in stock by years at the mines is given in a later table.

	Total reserves (gross tons).	Assessed equalized value.	Total value.	Total value per ton.	Assessed value per ton.
Minnesota[2], 1910	1,347,596,291	\$220,423,038			\$0.163
Michigan[3], 1911	196,354,883	93,938,629	\$119,485,000	\$0.61	0.473

[2]By Minnesota State Tax Commission.
[3]By Michigan State Tax Commission.

OWNERSHIPS.

It has been stated above that the titles to ore reserves are for the most part not vested in the operating companies. The mining business including control of ore reserves is, however, in the hands of the operating companies. In the period 1906-1911, 82 mines controlled by 34 operating companies including subsidiaries made shipments. The Oliver Iron Mining Co. of the U. S. Steel Corporation is the largest shipper but does not hold the position of preponderance in Michigan as in the Lake Superior region in general, as shown in the table below.

PERCENTAGE OF TOTAL IRON ORE SHIPMENTS BY UNITED STATES STEEL CORPORATION FROM MICHIGAN AND THE LAKE SUPERIOR REGION.[4]

	Total.	U. S. Steel Corporation.	Independent companies.	Percentage U. S. Steel Corporation.
1909.				
Lake Superior Region	42,586,869	21,876,246	20,710,623	51.4
Michigan	11,979,229	2,894,516	9,084,713	24.08
1910.				
Lake Superior Region	43,442,397	22,185,972	21,256,425	51.00
Michigan	11,402,508	2,975,251	9,427,257	25.07

[4]Figures for Lake Superior Region taken from report of American Iron and Steel Association for 1910.

Of the total ore reserves as estimated by Pin lay the independent companies control 142,047,548 tons or

72.3%, the U. S. Steel Corporation 54,307,335 tons or 27.7%.

MICHIGAN IRON ORE RESERVES BY RANGES, 1911.[5]

	Total reserves 1911.	Controlled by U. S. Steel Corporation.	Per cent.	Controlled by independent companies.	Per cent.
Gogebic	43,000,000	19,600,000	45.5	23,400,000	54.5
Iron River	42,122,000	1,400,000	3.3	40,722,000	96.7
Crystal Falls	8,054,000	625,000	7.7	7,429,000	92.3
Menominee, Metropolitan, Calumet	19,306,074	10,800,000	56	8,506,074	44.0
Marquette	77,126,651	21,616,335	28	55,510,316	72
Gwinn	6,746,158	266,000	3.9	6,480,158	96.1
	196,354,883	54,307,335	27.7	142,047,548	72.3

[5]Compiled from Appraisal of Michigan Mines, 1911, by J. R. Finlay.

Shipments by the Corporation and the Independent Companies seem to be about in proportion to reserves controlled.

PRICES OF MICHIGAN NATURAL IRON ORES AT LAKE ERIE PORTS FOR 1911 AND METHODS OF PRICE DETERMINATIONS.

In a subsequent table there is given the annual prices of Michigan iron ores at Lake Erie ports from 1855 to 1911. It must not, be understood that the prices there given were actually paid per ton of ore handled. The desirability of an ore of a given class for furnace use varies with the iron, phosphorous, and moisture percentages, and for different physical characteristics, such as porosity, density, lumpiness, etc.

The figures given in the table are called *base prices*. The *base price* serves as a point of departure for determining the actual value of an ore, and is paid only for ores which exactly fill certain arbitrarily fixed percentages of iron, phosphorous, and moisture. The ores as mined and sold vary in both directions from these arbitrarily fixed standards.

Iron ores are sold by the gross or long ton of 2,240 pounds. The amount of metallic iron in a long ton of ore is the primary or chief (though not the only) measure of its value. The *unit of value* should therefore be based on a *unit* of metallic iron. The *iron unit* has, therefore, been established as 1% of a long ton. The number of *iron units* in a ton of natural iron ore, i. e., which has its natural percentage of moisture, is determined by subtracting from 100% the percentage of moisture in the natural iron ore and multiplying the remainder by the percentage of iron in the ore dried at 212° F.

The base value of a *unit* of *iron* in the standard grades is obtained by dividing the *Valley price* (which is the Lake Erie .price, plus 60 cents) by the stipulated percentage of natural iron.

BASE PERCENTAGES, PRICES, AND IRON UNIT VALUES FOR LAKE SUPERIOR ORES, 1911.

Standard grade.	Natural iron per cent.	Phos. per cent.	Moist. per cent.	Iron dried per cent.	Lake Erie.	Valley.	Base unit value.
Old Range-Vermillion Bessemer	55.00	.045	10	61.12	$4.50	$5.10	$0.0927273
Mesabi Bessemer	55.00	.045	10	61.12	4.25	4.85	0.0881818
Old Range-Vermillion Non-Bessemer	51.50	....	12	58.52	3.70	4.30	0.0834951
Mesabi Non-Bessemer	51.50	....	12	58.52	3.50	4.10	0.0796116

The above table forms the basis for determining the prices of super standard and sub standard grades. The iron unit value in each grade fluctuates upward for each additional percent of natural iron and for Bessemer ores each decrease of .001% of phosphorous and downward for each decrease of 1% of natural iron and for Bessemer ores each increase of .001% of phosphorous.

The method for figuring premiums and penalties on Michigan ores, as illustrated in the Iron Trade Review[6] is as follows:

BESSEMER ORES.

"To arrive at the value in figuring old range Bessemer ores varying from the base of 55 per cent iron natural to 50 per cent iron natural, there should be allowed from the base price for each unit under 55 per cent iron natural down to 50 per cent iron natural, the value of the base unit.

Mesabi Bessemer ores are figured in exactly the same way as old range Bessemer ores. In the case of both Mesabi and the old range Bessemeres, to better compensate the furnace-men on ores when running under 50 per cent iron natural, in addition to the value that would be arrived at on an ore running 50 per cent iron natural, there should be allowed for the unit of iron from 49 per cent to 50 per cent iron natural, the base unit value plus 50 per cent, and for the unit 48 per cent to 49 per cent, the allowance should be the base unit value of the ore plus 100 per cent.

The phosphorous adjustment should be made as per accompanying table. On Bessemer old range ores running above 55 per cent iron natural and up to 60 per cent iron natural, the value is arrived at as follows:

METHOD OF FIGURING PENALTIES AND PREMIUMS ON OLD RANGE BESSEMER ORES. VALUE OF UNIT OF IRON. (INCREASE OR DECREASE) BETWEEN POINTS SHOWN ONLY. BASE UNIT, $0.10182.

For penalty.	Value.
Per cent natural iron:	
48 to 49	$0.20364
49 to 50	0.15273
50 to 51	0.10182
51 to 52	0.10182
52 to 53	0.10182
53 to 54	0.10182
54 to 55	0.10182
For premium.	
55 to 56	0.11182
56 to 57	0.12182
57 to 58	0.13182
58 to 59	0.14182
59 to 60	0.15182
60 to 61	0.10182
For each succeeding unit beyond 60 per cent	0.10182

For the value of the unit:

Per cent.	Cents.
55 to 56—Add base unit value plus	1
56 to 57—Add base unit value plus	2.
57 to 58—Add base unit value plus	3.
58 to 59—Add base unit value plus	4.
59 to 60—Add base unit value plus	5.

Thus adding a premium of 15 cents per ton on ore running as high as 60 per cent and above in the iron natural condition. For each unit above 60 per cent iron natural, add simply the value of the base unit.

The method of figuring penalties and premiums may be illustrated in the following example on old range Bessemer ores running over and under the base ore of 55 per cent iron natural:

Value of base ore 55 per cent iron natural and 0.045 per cent phosphorous at 212 degrees Fahr	$5.00
Descending scale—Ore guaranteed 48 per cent iron natural figured as follows:	
Per cent.	Cents.
55 to 50 equals five units at $0.10182	$0.5091
50 to 49 equals one unit at $0.10182 plus 50 per cent	0.15273
49 to 48 equals one unit at $0.10182 plus 100 per cent	0.20364
Deduct penalty	0.86547
Value of 48 per cent iron natural	$4.13
Value of base ore 55 per cent iron natural and 0.045 per cent phosphorous at 212 degrees Fahr	$5.00
Ascending scale—Ore guaranteed at 61 per cent iron natural, figured as follows:	
Per cent. Cents.	
55 to 56 equals one unit at $0.10182 plus 1	$0.11182
56 to 57 equals one unit at 0.10182 plus 2	0.12182
57 to 58 equals one unit at 0.10182 plus 3	0.13182
58 to 59 equals one unit at 0.10182 plus 4	0.14182
59 to 60 equals one unit at 0.10182 plus 5	0.15182
60 to 61 equals one unit at 0.10182	0.10182
Add premium	0.76092
Value of 61 per cent iron natural	$5.76

Any variation in phosphorous from the base of 0.045 per cent, to increase or decrease the value of ores, is figured by the table of phosphorous values.

NON-BESSEMER ORES.

In figuring the value of non-Bessemer ores, both old range and Mesabi, running from 50 per cent iron natural to 53 per cent iron natural, adjustments are made by addition and subtraction from the base ore at the rate of the base unit for each unit.

METHOD OF FIGURING PENALTIES AND PREMIUMS ON OLD RANGE NON-BESSEMER ORES. VALUE OF UNIT OF IRON. (INCREASE OR DECREASE) BETWEEN POINTS SHOWN ONLY.
Base Unit, $0.0932.

For penalty.	Value.
Per cent natural iron:	
48.00 to 49.00	$0.1864
49.00 to 50.00	0.1398
50.00 to 51.00	0.0932
51.00 to 51.50	0.0466
For premium.	
51.50 to 52.00	0.0466
52.00 to 53.00	0.0932
53.00 to 54.00	0.1032
54.00 to 55.00	0.1132
55.00 to 56.00	0.1232
56.00 to 57.00	0.1332
57.00 to 58.00	0.1432
58.00 to 59.00	0.0932
For each succeeding unit beyond 58.00 per cent	0.0932

In figuring the value of an iron ore running below 50 per cent iron natural, the allowance for the unit between 50 and 49 per cent, should be the base unit plus 50 per cent, and for the unit between 49 and 48 per cent the allowance should be the base unit value of the ore plus 100 per cent.

On ores running over 53 per cent iron natural, there should be added to the base unit:

Iron ore, per cent. Cents.
53 to 54—Base unit value plus 1.
54 to 55—Base unit value plus 2.
55 to 56—Base unit value plus 3.
56 to 57—Base unit value plus 4.
57 to 58—Base unit value plus 5.

In this way, adding a premium of 15 cents per ton to all ores running 58 per cent iron natural, or above, and for each unit above 58 per cent iron natural, add the value of the base unit. This method should be used on all ores in adjusting values and penalties down to 48 per cent iron natural condition.

The method of figuring penalties and premiums may be illustrated in the following example on old range non-Bessemer running over and under the base ore of 51.50 per cent iron natural:

Value of base ore 51.50 per cent iron natural	$4.20
Descending scale—Ore guaranteed 48 per cent iron natural.	
51.50 to 50.00 equals 1.50 units at $0.0932 plus 50 per cent	$0.1398
51.50 to 49.00 equals one unit at $0.0932 plus 50 per cent	0.1398
49.00 to 48.00 equals one unit at $0.0932 plus 100 per cent	0.1864
Penalty to deduct from base price	0.4660
	0.47
Value of old range Non-Bessemer ore at 48 per cent iron natural	$3.73
Value of base ore, 51.50 per cent iron natural	4.00
Ascending scale—Ore guaranteed 59 per cent iron natural:	
51.50 to 53.00 equals 1.50 units at $0.0932	$0.1398
53.00 to 54.00 equals one unit at $0.0932 plus 1 cent	0.1032
54.00 to 55.00 equals one unit at $0.0932 plus 2 cents	0.1132
55.00 to 56.00 equals one unit at $0.0932 plus 3 cents	0.1232
56.00 to 57.00 equals one unit at $0.0932 plus 4 cents	0.1332
57.00 to 58.00 equals one unit at $0.0932 plus 5 cents	0.1432
58.00 to 59.00 equals one unit at $0.0932	0.0932
Premium to add to base price	0.8490
	0.85
Value of old range Non-Bessemer ore at 59 per cent iron natural	$4.85

In using the accompanying phosphorous table in figuring Bessemer ores the per cent of phosphorous above or below 0.045, determines the value to be added to or subtracted from the value as determined from the iron content. If, for example, the ore has a phosphorous content of 0.046, 0.0080 is deducted from the value of the base unit. If the ore analyzes 0.044 per cent phosphorous, there must be added 0.0080, and so on, according to phosphorous content, the ore being more valuable for use in the Bessemer process as the phosphorous content decreases."

PHOSPHOROUS TABLE

Percentage phosphorous.	Rate of progression.	Phosphorous values.	Percentage phosphorous.	Rate of progression.	Phosphorous values.
0.070	0.0200	0.3500	0.037	0.0115	0.0780
0.069	0.0195	0.3300	0.036	0.0120	0.0900
0.068	0.0190	0.3105	0.035	0.0125	0.1025
0.067	0.0185	0.2915	0.034	0.0130	0.1155
0.066	0.0180	0.2730	0.033	0.0135	0.1290
0.065	0.0175	0.2550	0.032	0.0140	0.1430
0.064	0.0170	0.2375	0.031	0.0145	0.1575
0.063	0.0165	0.2205	0.030	0.0150	0.1725
0.062	0.0160	0.2040	0.029	0.0155	0.1880
0.061	0.0155	0.1880	0.028	0.0160	0.2040
0.060	0.0150	0.1725	0.027	0.0165	0.2205
0.059	0.0145	0.1575	0.026	0.0170	0.2375
0.058	0.0140	0.1430	0.025	0.0175	0.2550
0.057	0.0135	0.1290	0.024	0.0180	0.2730
0.056	0.0130	0.1155	0.023	0.1085	0.2915
0.055	0.0125	0.1025	0.022	0.0190	0.3105
0.054	0.0120	0.0900	0.021	0.0195	0.3300
0.053	0.0115	0.0780	0.020	0.0200	0.3500
0.052	0.0110	0.0665	0.019	0.0205	0.3705
0.051	0.0105	0.0555	0.018	0.0210	0.3915
0.050	0.0100	0.0450	0.017	0.0215	0.4130
0.049	0.0095	0.0350	0.016	0.0220	0.4350
0.048	0.0090	0.0255	0.015	0.0225	0.4575
0.047	0.0085	0.0165	0.014	0.0230	0.4805
0.046	0.0080	0.0080	0.013	0.0235	0.5040
0.045	**0.0000**	**0.0000**	0.012	0.0240	0.5280
0.044	0.0080	0.0080	0.011	0.0245	0.5525
0.043	0.0085	0.0165	0.010	0.0250	0.5775
0.042	0.0090	0.0255	0.009	0.0255	0.6030
0.041	0.0095	0.0350	0.008	0.0260	0.6290
0.040	0.0100	0.0450	0.007	0.0265	0.6555
0.039	0.0105	0.0555	0.006	0.0270	0.6825
0.038	0.0110	0.0665	0.005	0.0275	0.7100

[6] Volume XLVIII, pp. 495-498. March 9, 1911.

TRANSPORTATION.

Compared with other producing districts Michigan ore lies far from the main centers of smelting, manufacture and distribution. This disadvantage is more than offset by the richness of the ores. In the Lake Superior region Michigan enjoys over Minnesota the advantage of shorter rail and boat hauls and consequent lower freight rates.

The movement of ore to furnace is accomplished in three stages (1) mine to dock (2) lake haul (3) dock to furnace.

<u>Mine to dock</u>: At the mines the ore is loaded during the lake shipping season in part from pocket by gravity directly into hopper bottom or saddle back cars of 25 to 50 tons capacity and in part by steam shovel from stock

pile. During the winter season the ore is stock-piled. The loading charge is borne by the mining companies. The ore carrying railroads, of the Lake Superior Region with, distances, rates, etc., appear in the following table.[7] The Michigan tonnage is carried by independent roads, with the exception of the Lake Superior and Ishpeming Railway which is controlled by the Cleveland Cliffs and Jones-Laughlin interests.

ORE-CARRYING RAILROADS OF THE LAKE SUPERIOR REGION.

Railroads.	Ranges supplying traffic.	Principal range shipping points.	Lake termini at which ore docks are located.	Average haul, miles.	Approximate average cost per ton from mine to dock.
Duluth and Iron Range	Vermilion	Tower, Ely	Two Harbors, Minn	70-90	$0.90-$1.00
	Mesabi	Eveleth, Sparta, Biwabik		65	.80
Duluth, Mesabi and Northern	Mesabi	Virginia, Hibbing, Coleraine	Duluth, Minn	80	.60
Great Northern	Mesabi	Virginia, Hibbing, Nashwauk	Superior, Wis	120	.80
Chicago and Northwestern	Gogebic	Hurley, Ironwood, Bessemer, Wakefield	Ashland, Wis	40	
	Marquette	Michigamme, Negaunee	Escanaba, Mich	70	.40
	Swanzy	Princeton		45	
	Menominee	Iron Mountain, Norway		45	
	Crystal Falls	Crystal Falls, Amasa		80	
	Iron River	Iron River		83	
	Florence	Florence		63	
Duluth, Shore Shore and Atlantic	Marquette	Ishpeming, Negaunee, Michigamme	Marquette, Mich	12-15	.25
				35	
Lake Superior and Ishpeming	Marquette	Negaunee, Ishpeming	Marquette, Mich	12-15	.25
	Swanzy	Gwinn		36	
Wisconsin Central	Gogebic	Bessemer, Hurley, Ironwood	Ashland, Wis	50	.40
Chicago, Milwaukee and St. Paul	Menominee	Crystal Falls, Iron Mountain	Escanaba, Mich	40-60	.40

Ore Loading Docks: The loaded ore trains move out upon the ore docks where the ore is dropped directly into the dock pockets by opening the car bottoms. "There are many important considerations involved in the construction of the dock. The foundation is frequently 40 feet below water level and consists of a series of piling that cannot have much cross-bracing until the surface of the water is approximately reached. Above the water there is a height of from 60 to 70 feet and on top of this is the enormous moving loads of trains and locomotives, for an average of which 4,000,000 pounds is a low estimate. Air brakes on the trains stop them within a yard or two and consequently there is a pressure of about 2,500,000 foot-pounds to be taken up every time a train stops by the longitudinal bracing of the pier. Added to this is the fact that the center of permanent load may be 93 feet above foundation. The earlier docks were constructed of timber exclusively, but concrete and steel enter largely into the construction of the modern types. As the ships have grown larger and larger the docks have grown higher and higher in order to give the necessary slope to the chutes. Formerly the base of the pockets was only about 20 feet above water. In the more modern docks the hinge hold, however, is 40 feet or more, above the water level."[8] The ore pockets of the loading docks are spaced 12 feet centers. This corresponds to the spacing of the hatches on some modern boats enabling a cargo to be taken by them without a shifting of position. Previous to 1902 the type ore freighter had hatches spaced at 24 feet centers.

The problem of unloading involves rapid manipulation of trains and shunting of cars to maintain definite fixed composition of the ore in individual pockets. The ore runs from the pockets of the dock directly into the hatches of the freighters. The cost of handling the ore from train to boat aggregates four cents per ton.[9] The boats are loaded with surprising rapidity. On Oct. 10th, 1909 at Two Harbors, Minnesota, the steamer William E. Corey loaded 10,111 gross tons of ore in 39 minutes.[10] The storage capacity of the docks is small compared to the tonnage which annually passes through them.

The location and capacities of the loading docks handling Michigan ore is given in table below.

MICHIGAN ORE DOCKS.[3]

Railroad.	Location.	Dock No.	No. of pockets.	Storage capacity.	Height from water to center hinge hole.	Height from water to deck of dock.	Width of dock from outside to outside of partition posts.	Length of spouts.	Length of dock.	Angle of pockets.	Capacity per pocket to bottom of stringers.
				Tons.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Feet.	Deg. Min.	Cubic Ft.
Chicago and Northwestern	Escanaba, Mich	1	184	21,143	28 10	48 6	37	21	1,104	39 30	1,918
Chicago and Northwestern	Escanaba, Mich	3	226	28,792	31 2	52 8	37	27	1,356	45	1,969
Chicago and Northwestern	Escanaba, Mich	4	250	34,925	36 6	59 2	37	30	1,500	45	2,191
Chicago and Northwestern	Escanaba, Mich	5	202	29,310	28 6	53 3	37	21 8	1,212	40	2,832
Chicago and Northwestern	Escanaba, Mich	6	320	69,760	40	70	50 2	30	1,920	45	4,114
Chicago and Northwestern	Ashland, Wisconsin	1	234	42,120	40	70	50 2	30	1,404	45	3,915
Chicago and Northwestern	Ashland, Wisconsin	2	234	42,120	40	70	50 2	30	1,404	45	3,915
			1,650	268,170							
Duluth, South Shore and Atlantic	Marquette, Mich	4	200	28,000	27 9	47 3	36 8	21 1	1,200	39 45	1,839
Duluth, South Shore and Atlantic	Marquette, Mich	5	200	50,000	40	70 10	51	32 4	1,236	45	3,848
			400	78,000							
Lake Superior and Ishpeming	Marquette, Mich	4	200	36,000	30 9	54	50	27 7	1,232	38 40	2,713
		2[2]	200	50,000	43	75	54[1]	35	1,200	45	4,546
Chicago, Milwaukee and St. Paul	Escanaba, Mich	1	240	50,400	40 2½	66 6	52	120 27	1,500	45	2,900
Chicago, Milwaukee and St. Paul	Escanaba, Mich	2	240	63,500	40 11½	69 2	54	30 4½	1,500	45	3,150
			480	113,900							

[1]From outside to outside of semicircular bay.
[2]New dock will be in commission in 1912.
[3]From Mon. 52, U. S. Geological Survey except data on Lake Superior and Ishpeming Ry., new dock No. 2 which was submitted by the owners.

The Lake Haul: From the loading docks the ore is carried in bulk freighters to lower lake ports. The first shipment was billed by the Hon. Peter White of Marquette in 1852 and comprised five barrels of ore. Since that time the size of cargo has increased by leaps and bounds with the deepening and widening of the 800 locks and growth of capacity of lake freighters. The largest cargo in 1856 was 400 tons; in 1866, 697 tons; in 1876, 1,360 tons, in 1886, 2,450 tons; in 1895, 3,843 tons, in 1900, 7,450 tons and in 1910, 13,410 tons.[11]

Unloading Docks: The cost of unloading at the lower lake ports is borne by the vessels out of freight earnings. The unloading charge in 1910, was 15 cents per ton. Williams states that the actual cost with clam shell buckets is less than 5 cents per ton.[12]

Dock to Furnace: From the unloading docks the ore is distributed by rail haul to the furnaces. The freight rates to principal smelting centers as compiled by the Pittsburgh Chamber of Commerce are given below.[13]

	Average distance.	Average rate per gross ton.	Average rate per ton per mile in mills.
Pittsburgh district	160	0.96	6.0
M. & S. valleys	81	0.56	7.1
Ashland, Ky	256	0.90	3.5
Bellaire, O	167	0.60	3.6
Columbus, O	124	0.50	4.0
Jackson, O	219	0.62½	2.9
Josephine, Pa	228	0.85	3.7
Max Meadow, Va	537	1.55	2.9
Midland, Pa	115	0.78	6.8
Punxsutawney, Pa	181	0.60	3.3
Roanoke, Va	550	1.55	2.8
So. Bethlehem, Pa	353	1.45	4.1
Wellston, O	208	0.62½	3.0
Wheeling, W. Va	164	0.60	3.7
Johnstown, Pa	224	1.16	5.2
Ironton, O	251	0.90	3.6
Zanesville, O	146	0.55	3.8
Philadelphia, Pa	422	1.45	3.4
Sparrows Point, Md	470	1.50	3.2
Wilmington, Del	471	1.45	3.1

TOTAL COST OF TRANSPORTATION.

The average rate per ton mile of moving iron ore on the Great Lakes is stated by Williams to have been .7 mill in 1909. For the same year the corresponding figure for freight transportation on the Lake Shore Ry. is 5.16 mills. In 1907 the average cost per ton of transporting Lake Superior ore to the furnaces was $2.14.[14] Annual Lake Erie prices and rail and boat freight rates from Michigan ranges from 1855 to 1911 are given in a subsequent table.

[7]Mon. 52, U. S. Geological Survey, p. 495.

[8]Ralph D. Williams in Iron Trade Review. April 27, 1911.

[9]Monograph 52 U. S. Geological Survey, p. 496.

[10]R. D. Williams in Iron Trade Review, April 27, 1911.

[11]Crowell & Murray. The Iron Ores of Lake Superior, 1930, p. 23.

[12]Ralph D. Williams in Iron Trade Review, April 27, 1911.

[13]Iron Trade Review, January 18. 1912.

[14]Mon. 52, U. S. Geological Survey, p. 497.

IRON ORE ANALYSES.

Iron ore is bought and sold mainly on the basis of chemical composition. Each cargo is sampled and analyzed at the mine and the mine analyses are checked by the furnacemen or buyers. In order to insure uniformity of results standard methods of sampling and analyses have been developed.

The ore is first dried at 100° C. (212° F.) to expel the uncombined moisture. This insures uniformity of physical and chemical composition at both ends of the haul. When the ore is charged into the furnace, however, it contains more or less uncombined moisture making necessary the calculation from the "dry" analysis the "natural" analysis for the use of the furnacemen. All ore analyses are carefully recorded and average cargo analyses by mines are annually published by the Lake Superior Iron Ore Association.

The accuracy of the sampling and analyses is Illustrated by check figures on mine and furnace analyses on 21,030,909 tons of ore by the Oliver Mining Company in 1909.[15] The figures are given below.

	Iron.	Phos.	Silica.	Moisture.
Ave. Mine Analyses	59.19	.068	6.38	12.22
Ave. Furnace Analyses	59.04	.068	6.66	12.33

STANDARD CARGO SAMPLING METHOD.

The following is a description of the Sampling Method employed by the Independent Chemists of Cleveland.[16]

A continuous sample shall be taken from all cargoes, the weight of the sample varying with the size of the cargo.

This sample shall be taken with a galvanized iron scoop 3½" wide, 2¼" long and 1¼" deep, the handle 8" long; and with a hammer 12" long (the scoop holds approximately ½ pound).

It shall be the aim to take an equal bulk of ore from every point selected. When a lump is encountered a portion shall be broken off equal in bulk to a scoopful of soft ore. In sampling cargoes no sample shall be taken from the original outside surfaces on account of the presence of foreign matter and an undue proportion of fines.

SAMPLING OF SOFT ORE.

The sampler shall enter any hatch and begin sampling when the unloading machines have exposed five or six feet of the face.

In order to keep the size of samples within reasonable bounds and to gauge this size to the size of the boat, the sampler shall on cargoes up to 3,500 tons, begin sampling at a convenient point at the bottom of the face of the ore, and shall take one standard scoopful every two scoop lengths up the face of the ore to the top, and then shall move four scoop lengths to one side of the starting point before again sampling vertically. He shall continue in this manner keeping the above distances around the face of the ore to the place of beginning.

On cargoes from 3,500 to 6,000 tons, he shall use the two scoop lengths for vertical distances up the face of the ore, but move six scoop lengths horizontally.

On cargoes over 6,000 tons, he shall use the two scoop lengths for vertical distances up the face of the ore, but move eight scoop lengths horizontally. The sampler shall then enter the next hatch working, and proceed to sample in the very same way, and so continue in every hatch.

The sampler shall then begin over again in the hatch in which he first started and continue the sampling in all the hatches provided there has been sufficient ore removed in the hatches since the faces were sampled to expose fresh ore.

The sampler shall continue this method of sampling in each hatch worked, until there is less than one-tenth of the ore left.

In sampling horizontal surfaces, as in boats where scrapers are used, the sampler shall sample every two scoop lengths lengthwise of the boat, the spaces between the lines of sampling to be 4-6-8 scoop lengths, according to the tonnage as described before.

SAMPLING OF HARD ORE.

In sampling hard lump ore the sampler shall begin sampling, and use the same spacing as defined for soft ore, using hammer lengths instead of scoop lengths. At each point sampled he shall take lump or fine ore equal to one cubic inch. In taking this cubic inch, the sampler shall take an average from the lump from which the cubic inch is broken.

MOISTURE SAMPLE.

The moisture sample shall be taken from the standard sample in the following manner:

When as many cans of ore have been filled as the stage of unloading will permit, the lump ore shall be broken up and the entire amount of ore so far taken shall be mixed and quartered twice, and from the last quarters to be rejected one scoopful for each can in the original sample shall be put into the moisture can, provided the total number of scoopfuls taken will produce a moisture sample weighing about 20 lbs. In case a moisture sample of such weight is not produced, the sampler shall take two or more scoopfuls per can from the rejected quarters, enough to produce about 20 lbs.

The moisture sample shall at once be placed in a standard moisture can with tightly fitted cover. This shall be accurately weighed, dried at 100° C. until the weight is constant. The loss in weight will represent the moisture in the cargo.

At certain unloading points, it is desired of the consignee of the ore, that the entire sample shall be dried and crushed before any quartering is done. At such unloading points the moisture sample shall be taken as follows:

The sample shall take one round from each hatch when it is one-half unloaded, three scoop lengths vertically and twelve scoop. lengths horizontally, taking only ore from fresh surfaces which have not been exposed to sun or rain. It must be thoroughly mixed at once without breaking clown, and 20 lbs. placed in a standard moisture can.

Whenever it is not practical to hold the entire sample until the close of the sampling, before mixing and quartering, it may be quartered at convenient stages of the sampling. This must be done each time exactly alike, by breaking down to one-half inch, mixing and quartering twice, thus preserving the proper proportion of the whole sample.

If in the final quartering the last two quarters exceed a can full, the ore shall be quartered again and one quarter rejected.

The sample may be quartered on the vessel, or may be taken to some other place suitable for that purpose. Samples must be shipped to the crushing plant in standard cans.

CAR SAMPLING.

Not less than ten equal sized samples are taken from each car. When cars are loaded with fine ore with piles in opposite ends, at least five samples are taken from each pile; the first one at the apex of the pile, and the other four at points symmetrically arranged around the sides of the pile, two-thirds of the distance from the apex to the base of the pile or sides of the car. With cars loaded in the center, the system is the same, except that the center of the side of the pile lengthwise of the car, is the first point and the other four being symmetrically arranged around this point.

When the ten points are located in a car, each of them is supposed to represent a definite area, equal to one-tenth of the ore surface of the car. If the car contains all fine ore, then ten equal sized samples are taken, one from each of the points. If the car contains a mixture of fine and lump ore, with varying amounts of each in the areas included in the different divisions, then each area is judged separately and stamped accordingly. The fine and lump ore are-taken each in its proper proportions, the former with the scoop, the latter being chipped, or selected small pieces being taken, each about the size of the first joint of the thumb. The combined sample of fine, shipped and selected pieces from each area, equals the amount taken were it all fine ore. If the contents of the car were all lump ore, the proper sized pieces were chipped from four or five of the lumps in each of the ten areas, making forty or fifty pieces from each car, the total amount of the chipped pieces from each of the areas equalling the amount that would be taken were it all fine ore. All samples of fine ore are taken from well underneath the surface to obtain the ore in its natural state.

This method is based primarily on the assumption that a small representative portion of the ore taken from a large number of places in different parts of the cargo, will necessarily show the average composition of the cargo. Each year the Lake Superior ores are being more and more mixed, to establish certain grades. This mixture starts in the pockets of the loading docks, is continued as the various pockets are loaded in the boat and further mixed as the ore is unloaded from the boat into cares or in stock pile, and again mixed as the ore is unloaded at its destination. It is in the case of the more or less mixed ores that the present standard method is particularly applicable. The Independent Chemists fully realized the importance of the sampling, and are ever ready to consider suggestions, whereby the present method may be improved.

[15]Mon. 52 U. S, Geological Survey, p. 498.

[16]Quoted from Crowell & Murray, The Iron Ores of the Lake Superior Region, 1910, p. 29-32.

CHAPTER III. RECENT DEVELOPMENTS ON THE IRON RANGES.

With the exception of the Menominee, Calumet and Felch Mountain districts where exploration has been less active, recent development work on the Michigan iron ranges has in recent years added enormously to the available reserve iron ore tonnage. Some of the older mines have been rejuvenated by discovery of ore bodies at great depth and many new mines have been opened. Deep exploration, particularly in the Gogebic and Marquette districts has shown the existence of valuable large ore bodies and has removed the apprehension prevalent among many a few years ago regarding a possible general failure of the iron ore bodies to extend below moderate depths.

The Crystal Falls and Iron River districts, producers of non-Bessemer ore[1], have enjoyed several successive years of active exploration. The recent activity in these districts is due to the relative increase in consumption of non-Bessemer ore, to competition for reserves mainly among the independent producers of ore and iron products and to the existence in these districts of relatively large areas of unexplored ore-bearing formations under lands owned by a large number of small holders. The depression in the iron industry in 1911 had little effect on exploration in these districts.

In the following paragraphs there is briefly outlined recent progress in exploration and development on the different ranges.

[1]The Mansfield Mine produces Bessemer ore.

MENOMINEE RANGE.

In common reference the Menominee Range includes the Menominee, Crystal Falls, Iron River, Calumet and Felch Mountain (Metropolitan) districts in Michigan and the Florence district of Wisconsin. The location of these districts and their relations are shown in Fig. 5.

MENOMINEE DISTRICT.

OPENING OF THE DISTRICT: "The opening of the Menominee range may be stated as being in 1870, when the first logs were cut, and floated down the Menominee river in 1871. Also in 1871, John L. Buel in company with John Armstrong made the first reported discovery of iron ore, and in 1872 the first exploring party entered this region under the guidance of Dr. N. P. Hulst, representing the Milwaukee Iron Co. In 1873 the discovery made by Buell and Armstrong was explored and developed. In 1874 fifty-five tons of this ore was hauled to Menominee and smelted, the results being most satisfactory and gratifying. The first mining of iron ore and its smelting was followed by numerous explorations and the rapid development of mines."[2] Shipments began in 1877 from the Breen and Vulcan mines over the Menominee River Railroad (Chicago and Northwestern Ry.) which reached the village of Quinnesec in this year and was extended to Iron

Mountain in 1880. The district is served by the Chicago and Northwestern, the Chicago, Milwaukee and St. Paul and the Wisconsin and Michigan Railroads.

RECENT DEVELOPMENTS. WATER POWER, ETC.

<u>The relation between the Hanbury slate and Quinnesec Schist</u>: The true relations between the Quinnesec schist (effusive schistose greenstone) which occurs along the Menominee river and the Hanbury slates immediately adjacent to them on the north has long been a matter of doubt among geologists. W. S. Bayley concluded[3] that the Quinnesec schist is of Archean age and hence older and below the Hanbury slate. The contact between the two formations is not exposed in the Menominee district. If the Quinnesec schist is Archean, the occurrence of the Huronian formations along its northern edge is just short of a geological necessity, since under this view it is a legitimate inference that the schists are brought up on an anticlinal fold from the crest of which the Huronian series, which are developed in great thickness two to three miles north, have been eroded but should appear, in consequence of the structure, on the northern limb of the fold. The economic application of this theory consists in the possibility of the reappearance of the Vulcan iron-bearing member between the southern limits of the Hanbury slate and the Quinnesec schists.

Recent work, mainly by W. O. Hotchkiss,[4] in the Florence district of Wisconsin, has shown that the Quinnesec schists of that district, which are really continuous with the same formation of the southern part of the Menominee district, *overlie* the youngest Huronian rocks, and are probably of late Upper Huronian age. The acceptance of this view clears up the question entirely and relieves us of the awkward necessity of explaining under the former theory why the Vulcan formation does not reappear, somewhere between the Hanbury slate and the Quinnesec schists. Exploration has not yet proved or disproved the absence of the Vulcan formation here, the reluctance of mining interests to undertake such exploration reflecting a disbelief in the probability of its occurrence. In the light of present information such disbelief is well founded.

<u>Exploration in the Hanbury Slate</u>. Some exploration has been done in the Hanbury slate none of which, however, has given encouragement for further work. Most of the formation is drift covered but enough is known to establish the fact that within it are beds of slaty siliceous iron carbonate and some ferruginous chert. The occurrence of ore bodies in the Hanbury formation is therefore a possibility, although not at present in the least degree an alluring one.

<u>Water Power</u>: The Menominee district possess an asset in the water powers of the Menominee river which bids fair to be in the future vigorously utilized. For many years a great compressor plant has been in operation at the Upper Quinnesec falls from which compressed air is conducted to the Chapin mine at Iron Mountain. The Sturgeon Palls is utilized by the Penn Iron Mining Co. in generating electric power which has displaced steam almost entirely for mine power.

The latest power project is that of the Peninsula Power Co., begun in 1911 at Twin Falls in Sec. 12, T. 40 N., R, 31 W. The dam is located at the lower fall and will develop a head of 42 feet, raising the water to a depth of 12½ feet over the rock sill of the tipper fall. The plant is designed to generate 5,000 electrical H. P. which will be distributed over transmission lines to all of the mining districts in the Menominee ranges. The plant will be operated on the customs plan and the power sold to mines tributary to the various transmission lines.

<u>ORE RESERVES.</u>

The ore reserves of the Menominee district reported by Mr. J. R. Finlay to the Michigan State Tax Commission are given below.

ORE RESERVES. MENOMINEE DISTRICT. 1911.

Mine.	Reported in sight above bottom level.	Total tonnage expected by J. R. Finlay.
Cyclops, Norway, E. & W. Vulcan, Curry, Brier Hill	1,537,245	3,800,000
Pewabic	1,233,000	1,233,000
Loretto	1,107,424	2,000,000
Chapin	4,194,679	9,000,000
Aragon	1,085,000	1,800,000
Millie	20,000	400,000
Breen	....	....
Vivian	....	....
Quinnesec	....	....
Munro[5]	423,074	....
	9,600,422	18,233,000

[5]Ores are low grade. Not included in reserve tonnage estimate.

In contrast to the conditions in the Crystal Falls district and particularly the Iron River district the reserve tonnage is all in mines which have been producers for many years. The possibilities for opening new mines in the Menominee district are not, however, by any means exhausted.

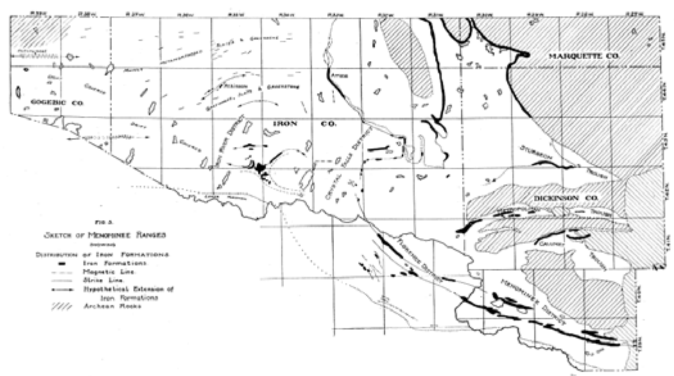


Figure 5. Sketch map of Menominee ranges showing distribution of iron formations.

CALUMET TROUGH.

Location and Extent: The Calumet trough is a synclinorium of Huronian sediments lying north of the Menominee district and trending in a general E-W direction through T. 41 N., Rs. 27, 28, 29 and 30 W. On the east the trough is lost beneath a covering of

Paleozoic rocks and on the west it merges with the Menominee and Florence districts. (Fig. 5.)

The Iron (Vulcan) Formation. Distribution and Occurrences: The iron formation of the Calumet trough has been traced mainly by magnetic methods. (Fig. 6.) Natural exposures are rare. The formation has been opened at the old Hancock exploration in Sec. 30, T. 41 N., R. 27 W., at the Calumet Mine and vicinity in sections 8 and 9 and in pits and drill holes on Sections 16, 17 and 18, T. 41 N., E. 28 W. and farther east in an old shaft on the N. E. ¼ of the N. W. ¼ of Sec. 15, T. 41 N., R. 29 W. On the east end of the trough in township 40 and 41 N., Rs. 25, 26, and 27 W. are several small magnetic fields (Fig. 7) which indicates the presence of iron formation beneath the horizontal beds of sandstone and limestone which are here of considerable thickness. In the N. W. part of Section 3, T. 41 N., R. 37 W., a drill hole, put down several years ago, passed through 68 feet of limestone into steeply inclined gray quartzites and hard ferruginous slates, containing many streaks and then layers of red and gray hematite and magnetite. There is little in this hole to indicate that the formation would repay development.

Outside the Calumet mine, explorations in the Calumet trough have developed no iron formation of promising character.

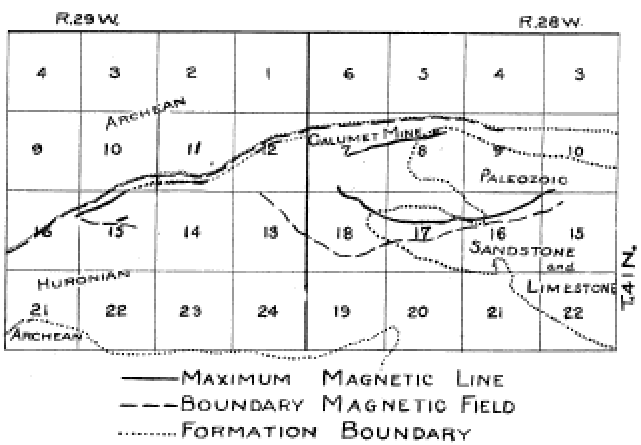


Figure 6. Magnetic lines indicating distribution of iron formation. From private surveys by R. C. Allen. Edw. Steidtman and others.

Calumet Mine: The strike of the iron formation at the Calumet mine is about N. 80° E, the dip varies from vertical to 80° south. There are three distinct iron bearing beds. The lens farthest north is about 60 feet thick, is overlain to the south by 35 feet of soft iron stained altered slate, 15 feet of iron formation, 15 feet of altered slate, 60 feet of iron formation. The upper iron bearing bed has a hanging wall of black slate. Beneath the iron bearing series lie in order the quartz schist, quartzite (combined thickness 250 feet) and dolomite of the Lower Huronian.

The iron formation consists of banded ferruginous chert and lean iron ore running between 40% and 50% iron. All of the ore in sight is low grade although some small high grade pockets have been mined. The Calumet mine has never been worked actively except at intermittent short periods. It was closed in May, 1910 and has on stock pile about 75,000 tons of 42% ore.

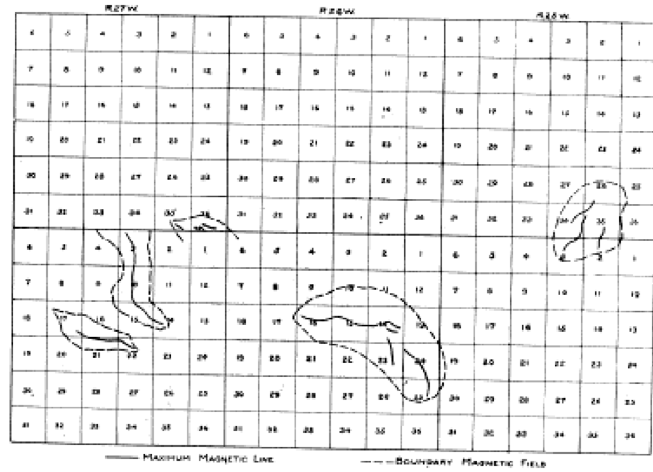


Figure 7. Magnetic fields in southwest extension of Calumet trough. Compiled from private surveys.

THE METROPOLITAN TROUGH. (FELCH MOUNTAIN DISTRICT.)

The Metropolitan trough is a narrow complex synclinorium of Huronian rocks trending E.-W. through the southern portions of T. 42 N., Rs. 28, 29 and 30 west, thence across the northwest corner of T. 41 N., R, 30 W. into section 12, T. 41 N., R. 31 W. beyond which the structure is lost underneath glacial drift. The synclinorium is some eighteen miles long and varies from a half up to nearly two miles in width.

Distribution of the Iron (Vulcan) Formation. "In the Felch Mountain district the Vulcan formation is magnetic and has been traced by means of compass and dip needle. Excellent natural as well as numerous artificial exposures render the data concerning the distribution of the formation very satisfactory.

On the west the iron-bearing formation is exposed in ledges and test pits in sec. 5, T. 41 N., R. 30 W., from which a line of attraction extends southwestward through sec. 6 into sec. 12, T. 41 N., R. 31 W., where it is lost. The presence of the Vulcan formation through secs. 34, 35, and 36, T. 42 N., R. 30 W., is shown by one principal and other minor lines of attraction, as well as by test pits and outcrops. The principal line of attraction begins in sec. 34, near the southwest corner, and runs to the northeast, in conformity with the strike of the northern belt of dolomite, finally ending in the northeastern portion of sec. 36. This line of attraction is very vigorous and strongly marked. Two other lines, parallel with the principal line but more feeble and much shorter, cross the boundary between secs. 35 and 36. Another line, marking the west end of the Groveland syncline, begins near the center of sec. 36 and continues for 1½ miles eastward to the eastern portion of sec. 31, T. 42 N., R. 29 W. Along the western portion of this line are many test pits and in sec. 31 occur the fine exposures of the Groveland hill.

Another line of attraction begins 400 paces north of the center of sec. 32, T. 42 N., R. 29 W. which may be followed eastward without interruption nearly to the east line of sec. 33 of the same township. Along this line, which is comparatively feeble and crosses wet ground, there are but few test pits. In the eastern part of sec. 33, beyond the point at which the attraction ceases, many pits have been sunk-to and into the Felch schist, which is there somewhat ferruginous. From this point eastward for 4 miles the Vulcan formation has not been recognized.

In the northern part of secs. 32 and 33,. T. 42 N., R. 28 W., the ferruginous rocks are well exposed on Felch Mountain for nearly a mile along the strike, and may be identified for half a mile farther by the vigorous disturbances produced in the magnetic needles. In the S. E. ¼ sec. 33 the Vulcan formation is again encountered in a small and much disturbed area, in faulted contact with the Archean."[6]

Groveland Mine: The only active mine on the Metropolitan range is the Groveland in sec. 31, T. 42, R. 39, operated by the Groveland Mining Co. The mine is developed on three levels to a depth of 275 feet. The ore is hard blue hematite and specular hematite of low grade. A forty acre tract adjacent to the Groveland on the east was recently drilled by the Breitung interests. The formation here is of the character shown in the Groveland workings.

CRYSTAL FALLS DISTRICT.

The opening of the Crystal Falls district dates from the spring of 1882 when shipments began over the Chicago and Northwestern Ry., which was completed from Stager in April of that year. In 1888 a branch was built to Amasa thus affording an outlet for the ore of that vicinity. The Chicago, Milwaukee and St. Paul Ry. was built from Channing to Amasa in 1893, the vicinity of Crystal Falls being served by a spur from Kelso.

As in the Iron River district, ore had been discovered and considerable development work accomplished before the building of the railroad, which came after the prospectors had demonstrated the ore bearing possibilities of the district. The earliest of these prospectors was Mr. "Jack" Armstrong who is credited with the first discovery of ore, the sight being on Lot 3, sec. 20, 43-32.

The production of the district rose steadily to 1892 when 603,048 tons were shipped. This figure was not reattained until 1898 due to slump following the panic of 1893. Since 1898 the production has fluctuated between 1,631,484 tons in 1907 and 629,602 tons the following year.

THE IRON FORMATION AND ITS OCCURRENCES. RECENT DEVELOPMENTS.

The distribution of the iron (Vulcan) formation is indicated in Fig. 5. The thickness of the formation is not above 300 to 400 feet. As in the Iron River district the iron formation occurs in lenses in the Michigamme slate and at different horizons in the slate and presents therefore precisely similar (but not so great) difficulties to successful structural interpretation. At Amasa and in the vicinity of Crystal Falls, the iron formation is separated from the Hemlock greenstone by small but variable thicknesses of slate and is therefore near the base of the Upper Huronian series.

In the northeastern part of the district a great oval area of Archean and Lower Huronian rocks is almost surrounded by a belt of iron formation. That on the east side of the oval is believed to be of Negaunee age but that on the west is Upper Huronian. Little is known of the character of the Negaunee formation over the greater part of the belt on the west. It was mapped mainly on the basis of a magnetic line but is partially opened in the Sholdice exploration in the S. E. ¼ of the N. E. ¼ of Section 21, T. 45 N., R. 31 W. On the Sholdice exploration the formation is fine grained, dense banded, hematite and reddish quartz or chert. The hematite bands vary from less than an inch to a few feet in width. The ore thus far shown is too lean for present use.

On the west side of this oval, going southward, the first important exploration is the Red Rock (Channing) on the N. E. ¼ of the S. E. ¼ of Sec. 20, T. 45 N., R. 33 W. The exploration was temporarily abandoned in 1911 by the Verona Mining Co. A shaft located 180' east and 125' north of the center of the S. E. ¼ of the section was sunk 327'. Considerable lean ore was encountered on the first level and on the second level west of the shaft at 228' from the surface ore was found which, however, did not extend downward to the third level. The strike of the formation is N. E.-S. W.

From the Red Rock the iron formation probably extends at least as far north as the middle of section 16, T. 45, R. 33, from which point south through the Red Rock property and thence into the iron formation at Amasa is a practically continuous magnetic belt. At Amasa are the Hemlock and Michigan mines. The Hemlock is developed to the fourteenth level at a vertical depth of 1,020 feet. The shaft is in greenstone and is inclined at about 60°. The ore is separated from the greenstone by a slight thickness of slate but at least in one place the iron formation lies directly on the greenstone The ore in this mine from the 12th level to the surface averaged 15' to 20' thick and formed a tabular body striking N. W.-S. E. and dipping S. W. at about 70° with a minor fold on the 6th level throwing the ore about 20' further west on lower levels . At the 12th level the dip flattened out, the ore maintaining a thickness of about 20' and pitching at an angle of about 20° northwest through the 13th level down to about the 14th level where it apparently disappears. On the failure or success of efforts to locate a possible extension of the ore body depends the life of the Hemlock mine. The outlook is not at present very encouraging.

The Hemlock ore body has on most levels extended southeast into the Michigan mine of the Oliver Mining Co. The Michigan has been closed for much of the time in recent years and is not being actively worked. About two miles southeast of the Michigan mine is the Gibson Exploration where work has been under way for a number of years by the Rogers-Brown Ore Co. The Gibson is presumably on the same iron bearing horizon as the Hemlock and Michigan mines but has not developed any considerable tonnage of marketable ore. The pumps were pulled and the mine closed in July, 1911. A considerable tonnage which had accumulated in stock pile was shipped.

Between the Michigan and the Gibson, the iron formation is being explored by the Pickands-Mather interests on Sec. 9, T. 44 N., R. 33 W. The exploration is known as the Warner-Corry. The results of the work here thus far show a formation of promising character.

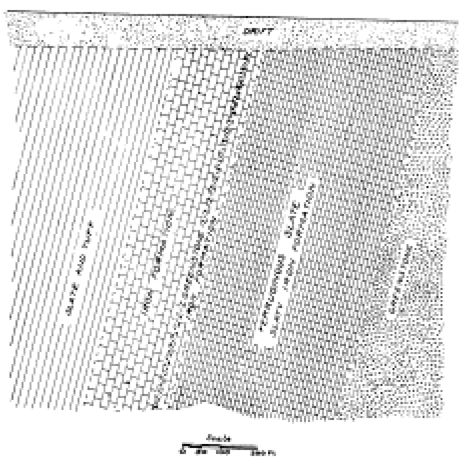


Figure 8. Generalized section showing thickness and relations of the iron formation on the Porter-Amasa property. Compiled from plats furnished by the E. J. Longyear Co.

Southeast of the Gibson on the N. E. ¼ of Section 22, T. 44 N., R. 33 W. is the Porter-Amasa exploration owned by the Nevada Land Co. Drilling by the Shenango Furnace Co. demonstrated the presence of iron formation here some years ago. Recent exploration by the E. J. Longyear Co. has revealed an ore body of considerable dimensions, part of it of Bessemer grade. The ore body so far as known from drill records is of tabular shape and steeply inclined to the southwest similar to other deposits on this belt. Steps have not yet been taken to open a mine but it is probable that an ore body of this desirable quality will not long remain unopened.

Southeast of the Porter-Amasa exploration work, has been in progress by the Rogers-Brown Ore Co. and the St. Clair interests on Sec. 23 and by the Florence Iron Co. on Sec. 36, T. 44 N., R. 33 W. These properties are said to be crossed by a magnetic line and it is thought that the iron bearing horizon of the Hemlock, Michigan, Gibson and Porter properties passes through the section. (Fig. 5) Ore is reported to have been cut on Sec. 26 to the N. W. and also on Sec. 6, T. 43, R. 32, adjacent on the S. E.

Still farther southeast in the northern part of Sec. 14, T. 43 N. R. 32 W. the iron bearing horizon was penetrated in drill holes several years ago. The records of some of these holes are of encouraging character and unite to further exploration.

From Section 14, the iron bearing horizon turns south and passes through the Hollister, McDonald and Armenia mines. The Hollister mine has been developed on mine levels to a depth of 750 feet. The strike of the formations here is 10° E. of south. The workings are all west of the shaft in a steeply westward dipping series of slate and iron formation. East of the shaft about 1,500' are greenstone outcrops. The Hollister ore runs so high in moisture that experiments have been conducted on drying before shipment. A plant was installed by G. C. Olmstead in the summer of 1911 with capacity of 300 tons per 24 hours. Ore is taken from the skips and, broken through a grizzly, from which it is caught on a Robbins belt conveyor and carried into a hopper feed discharging into an inclined revolving drum heated by stokers. Hot gases are carried through the drum over the ore and out the stack. The ore is received at the low end of the revolving drum by a bucket elevator and delivered to train cars operated on trestle above stock pile. The Hollister experiments if thoroughly carried out will determine the commercial feasibility of ore drying at the mine. If the saving on freight and ultimately fuel in smelting is greater than the cost of drying the process will be profitable.

South of the Hollister about ¾ mile on the S. E. ¼ of the N. E. ¼ of T. 43 N., R. 32 W. is the McDonald, a new property which has been in course of development by the McDonald Mining Co. for the past four years. The shaft is now 300' deep and the property is partly developed on three levels. The iron formation is said by Capt. A. E. Drake in charge to measure about 500' wide, is highly folded and brecciated and lies on a slate foot wall dipping steeply east. The workings lie west of the shaft which is in slate. Some ore is showing on three levels. The bodies thus far opened are irregular small concentrations but the property is only partially explored and its possibilities are not yet tested.

East of the Hollister and McDonald mines, the slate-iron formation series is caught in a deep southward projecting embayment in the Hemlock greenstone. In this embayment is the site of the old Bird exploration. The shaft, 80' to 100' deep, is on the S. E. 14 of the S. E. ¼ of Sec. 13, T. 43 N., R. 32 W. The Bird section is interesting in that it displays on exposure and in an E.-W. trench a short distance north of the shaft the relations between the greenstone and the slate-iron formation series. Beginning on the top of the greenstone belt west of the shaft and proceeding eastward there is exposed in a steeply eastward dipping series:

0-15 paces.	Six flows of green stone, the top and bottom of each flow showing well developed amygdaloidal textures.
20-26 "	Greenstone flow.
26-29 "	Greenstone flow.
29-34 "	Greenstone flow.
34.48 "	Covered.
45-53 "	Greenstone flow.
53-91 "	Greenstone flow.
91-106 "	Lean ferruginous slate.
106-118 "	Greenstone-jasper conglomerate.
118-135 "	Iron formation.
135-158 "	Ferruginous slate.
158-	Beyond 158 paces a trench continues into a swamp but no rock is showing in the bottom. Across the swamp to the east are greenstone outcrops.

This succession indicates the conformable relations and interbedding of the greenstone flows and iron formation slate rocks. In some flows there are banded siliceous jaspery stringers following around between the ellipsoids, simulating flow structure. In one instance a stringer of this material is 8 inches wide and 8 feet long passing off the outcrop beneath the drift covering. Some of the jasper bands plainly follow flow lines in the greenstone and are plainly contemporaneous and genetically related in origin to the greenstone. (Compare Porter-Amasa Section, Fig. 8.)

East of the Bird location in the N. W. ¼ of Section 20, T. 43 N., R. 31 W. is the Mansfield mine which has the distinction of being the only producer of Bessemer ore in the Crystal Falls district. The mine is located in a narrow tongue of slate, averaging about a quarter of a mile wide, extending northward 3 miles into the greenstone from sections 31 and 32 into the south edge of sections 7 and 8. The Mansfield ore bearing horizon is from 8 to 15 feet thick dipping steeply westward between slate walls. The mine is developed to a depth of 1,390 feet.

About ¼; mile south of the McDonald is the Armenia mine on the N. E. ¼ of the S. E. ¼ of Section 23, T. 42 N., R. 32 W., operated by Corrigan-McKinney Co. The mine is developed to the seventh level at a depth of 690 feet. From the Armenia it is about ¾ mile slightly east of south to the old Lee Peck exploration. From the vicinity of the Lee Peck the iron bearing horizon probably extends a little south of east through the old Hope exploration, which is in promising looking iron formation, and thence on about the same course through the old May exploration in the S. E. ¼ of the S. E. ¼ of Section 28, and thence east through the Kimball mine on the S. E. ¼ of the S. E. ¼ of Sec. 29, a low grade property controlled by Corrigan, McKinney Co. which has been idle for a number of years.

From the Kimball it is about 2 miles slightly south of east through the old Shaefer mine to the Tobin mine and the iron formation, from all available structural data, if continuous, should cross the intervening area. The Tobin is developed to the eleventh level at 1,100 feet depth. Development is in progress on the twelfth level 125 feet lower.

One of the most important explorations of the year 1911 is that in progress by the M. A. Hanna Co. just south of the Tobin on Sec. 31, T. 43 N., R. 32 W., lying between the Tobin mine on the north and the Dunn on the south. The property is known as the Monongahela-Carpenter. The results of over a year's drilling has shown up a considerable tonnage of ore of good grade and the Monongahela-Carpenter bids fair to become one of the large mines, of the district.

South of the Monongahela in the N. E. ¼ of Sec, 1, T. 42 N., R. 33 W., is the Dunn mine the deepest and one of the oldest mines in the district. It is opened to the 11th level at a depth of 1,420 feet. The reserves in the mine are approaching exhaustion and its continued operation will depend on opening new tonnage which is considered by the management not likely to occur.

From the Dunn the trend of the iron formation continues southward through the South Dunn exploration on the N. E. 14 of the S. E. ¼ of Section 1, T. 42 N., R. 33 W. Exploration was conducted here in 1908 by the Munroe Iron Mining Co. A shaft was sunk and considerable underground work was done which on the whole seemed not to yield satisfactory results and the exploration was abandoned. The best ore was encountered south of the shaft in a drift from the 175 foot level which passed through forty feet averaging about 60% in iron, non-Bessemer. Although the formation is twisted and contorted, the general strike is probably about south. In this general direction a local magnetic field occurs on the N.-S. quarter line of the section about ¾ mile from the south Dunn shaft.

Still farther south in sections 12, 13 and 14 is the Alpha-Mastodon-Delphic area. This area which has not produced for many years has been rejuvenated by recent exploratory work of the Nevada Land Co. Drilling was conducted for over two years on the old Alpha location (S. W. ¼ of S. W. ¼ of Sec. 12, T. 42 N., R. 33 W.) and the vicinity of the workings thoroughly explored without encouraging result. Proceeding southeastward on the strike of the iron formation with closely spaced drill holes ore was finally located near the south line of the section in a swamp along Mastodon Creek. The ore lies on a gray slate foot wall dipping about 35° S. E., is of high grade non-Bessemer quality and the deposit has already assumed very considerable dimensions. Drilling is still in progress.

Considerable drilling has also been done by the Nevada Land Co. on the old Delphic location (N. W. ¼ of S. E. ¼ of Sec. 24, T. 42 N., R. 33 W.) and is still in progress. The iron formation strikes northeast from the old Delphic pit and has been followed by drilling into the swamp in the northern part of the section. From the Delphic location the general trend of the slate iron formation series continues apparently slightly south of east into Wisconsin.

We have now traced for upwards of 30 miles a practically continuous iron bearing horizon. Along this belt there doubtless remains to be discovered many ore deposits in addition to these now known. Considering the amount of explorable ground on this belt with the character and number of deposits already known it is .probably true that its reserves are hardly more than beginning to be known.

North of Crystal Falls is a second productive belt trending from the Ravenna exploration in Sec. 19, T. 43 N., R. 32 W., east through the Bristol and Great Western mines and thence apparently northeast through the Crystal Falls and Hill Top properties into the Victoria exploration in the N. W. ¼ of the N. W. ¼ of Sec. 22. The active mines on this belt are the Bristol and Great Western but the Great Western was practically idle during 1911. This belt is paralled on the north by greenstone to which it bears about the same stratigraphic relation that is exhibited by the Amasa belt discussed above. It is, however, apparently considerably higher up in the slate series.

The Ravenna is a recent exploration of M. A. Hanna & Co. It adjoins the Bristol on the west. Considerable drilling has been done and a shaft put down from which drifting is being done on the first level proving the continuation of the iron, formation from the Bristol property. Some ore has been encountered but as yet not in any considerable quantity.

The Bristol Mine (N. E. ¼ of S. E. ¼ of Sec. 19, T. 43 N., R. 32 W.) is developed to a depth of 960 feet. The iron formation strikes E.-W., dips vertical or steeply southward and is about 350' thick enclosed in black slate walls. In the west end of the mine a black slate wedge appears in the middle of the formation. It is 50' thick at the hoisting shaft and widens westward. Its thickness is included in that of the iron formation. The ore is now being drawn from a low grade body running 49 to 55% iron and 3% manganese. It lies just south of the open pit and extends downward to the 8th level and below dipping south at a high angle and pitching slightly west. The workings extend to the east line of the property but in this vicinity the ore runs only about 45% iron. The ore in the Bristol mine is apparently not related to slate walls or slate troughs but is simply enriched layers in the iron formation which may occur anywhere in the mine. The phosphorous content of the ore has been about the same throughout the mine but the sulphur content according to Capt. Bjork rises with depth. A new shaft is being sunk in black slate about 360' N. W. of the hoisting shaft now in use.

Geological conditions very similar to those of the Bristol mine are met with in other properties on this belt including the Great Western.

An important recent development on this belt is that made by Mr. B. F. Neely east of the Great Western mine on the N. E. ¼ of the S. E. ¼ of Section 21, 43 N., 32 W. A large tonnage of ore has been located by drilling on this description but as yet no steps have been taken to mine it. This deposit is considered practically an extension of the Great Western ore body.

From the above location the iron formation extends northward through the Crystal Falls and Hilltop mines which have long been idle into the Victoria exploration (N. W. ¼ of N. W. ¼ of Sec. 22) where it is reported that development work will be resumed in the near future.

ORE RESERVES.

The following is the estimated ore reserves of the district reported by J. R. Finlay to the Michigan State Tax Commission in 1911.

ORE RESERVES, CRYSTAL FALLS DISTRICT, 1911.

Mine.	Reported in sight above bottom level.	Total tonnage expected by J. R. Finlay.
Hollister	....	....
Crystal Falls	42,000	500,000
McDonald	10,000	....
Mansfield	32,000	525,000
Fairbanks	....	....
Bristol	522,000	1,500,000
Armenia	50,300	550,000
Great Western	97,300	800,000
Tobin	135,300	1,800,000
Kimball	....	....
Dunn	67,000	117,000
Michigan	78,000	100,000
Hemlock	125,000	180,000
Channing	75,000	75,000
Youngstown	....	40,000
Amasa-Porter	....	330,000
Alpha	....	60,000
Neely	....	587,000
Hill Top	....	10,000
Monongahela-Carpenter	....	320,000
Extension Great Western	....	200,000
	1,233,900	8,054,000

From the above estimates it appears that the reserves are equal to about half of the total shipments and that 21 per cent of the reserves are in properties which have not reached the producing stage.

IRON RIVER DISTRICT.

The Iron River district lies north, east, south and west of Iron River the center of industry. The district has no natural well defined geological boundaries, except on the south. The area of mining operations is being constantly extended.

Ore was discovered by Mr. Harvey Mellen, a United States land surveyor on Aug. 8th, 1851, on the west face of Stambaugh hill in Sec. 36, T. 43 N., R. 35 W. The opening of the district dates from the fall of 1882 when the Chicago and Northwestern Ry. reached the district with a spur from Iron River Junction, now Stager. In 1887 this line was completed to Ironwood.

From 1882 to 1893 the only important shippers were the Iron River and Beta mines, the former being on the site of Mr. Mellen's discovery of 1851. The shipments to 1893 totaled 1,130,444 tons. From 1893 to 1899 practically no mining was done but since the latter date development has gone steadily and in recent years rapidly forward.

Regarding the distribution of the iron formation much is yet to be known because of the general absence of exposures and the necessity of reliance on information furnished by underground exploration. Rapid as has been the exploration of this district in recent years the results are still far from adequate for purposes of general mapping. The areas of known iron formation were mapped by the Michigan Geological Survey in 1909.[7] These areas have been considerably extended by recent work.

DISTRIBUTION OF THE IRON FORMATION.

The known main occurrences of the Vulcan formation may be referred to three different areas, viz., (1) the Jumbo belt just south of Brule river in Florence county, Wisconsin, about 1½ mile east of Saunders; (2) the central producing area of unestablished boundaries; (3) the Morrison Creek belt in Sec. 24, T. 44 N., R. 35 W. and (4) the Atkinson belt, southwest of Atkinson. Exploration has not demonstrated that the Jumbo, Morrison Creek, and Atkinson belts carry important ore bodies. Such exploration as they have received has not been encouraging.

The Vulcan formation of the producing area has a thickness at maximum of 300 to 400 feet. It is nearly everywhere steeply inclined and in consequence its exposures are generally narrow and not greatly in excess of its thickness. From the studies which have been made in this district, I am convinced that the Vulcan formation occurs here in more or less discontinuous lenses in the Michigamme slate. A given horizon which carries in one place slate may in another not far distant carry iron formation and vice versa. This concept has a direct bearing on exploration. In one sense it simplifies the structural problems, which will in time be solved as new data is obtained, and in another sense it complicates the problems. If true, it limits the value of the iron formation as a horizon marker over any but local areas but on the other hand obviates the necessity of introducing great faulting and improbable structures to account for the facts of distribution. These considerations do not, however, complicate the problem of the general structure of the district of which much is known.

WESTWARD EXTENSION OF THE IRON RIVER IRON-BEARING SERIES.

In 1910 I called attention[8] to features of general structure which seemed to indicate a westward extension of the iron bearing series of the Iron River district. Mining men have had in mind for some rears a possible connection between the Gogebic and Iron River districts. On early general geological maps the supposed Archean boundary to the south of the Menominee ranges was brought in from Wisconsin in the vicinity of Lac Vieux Desert and extended thence, in general, northwesterly to connect with the north boundary of the Archean mass which lies immediately south of the Gogebic district.

The work of 1909 in the Iron River district encouraged us to push on westward in quest mainly of information bearing on the problem of a possible westward extension of the iron-bearing series of the Iron River district. The results thus far have not been altogether discouraging and I shall outline below the aspects of the problem as they appear.

Referring now to Fig. 5, it will be seen that the producing area of the Iron River district is cut off on the south by the Lower Huronian series striking west into the south part of T. 42 N., R. 36 W. On the north it is limited by a great series of presumably but not certainly younger metamorphosed graywackes, slates and volcanic greenstones trending on the average a little south of west. Between the Lower Huronian on the south, and its projected westward extension, and the graywacke-slate-greenstone mass on the north lie the drift covered townships 42 N., Rs. 36, 37 and 38 W. west of Iron River. Here, if anywhere, lies the westward extension of the Iron River series. In this area there are no exposures. Dip needle readings taken on N.-S. lines run at ¼ and ½ mile intervals show no appreciable variations up to the middle of T. 43 N., R. 37 W. Beginning in Section 16 of this township a magnetic belt extends through sections 17 and 18 into Section 13, T. 43 N., R. 38 W. where it dies out reappearing, however, in section 15 extending thence westerly across the state boundary into Wisconsin. (Fig. 9.)

This magnetic belt is probably caused by an iron formation. It indicates the strike or trend of the formations in this area which is in line with the supposed strike determined as above by study of the structure of the rocks lying north and south of the Iron River iron bearing series and their westward extension. Presumably, the probable iron formation underlying this magnetic belt, and probably extending eastward where no magnetic variations occur, is of Upper Huronian age and is decidedly worth exploring.

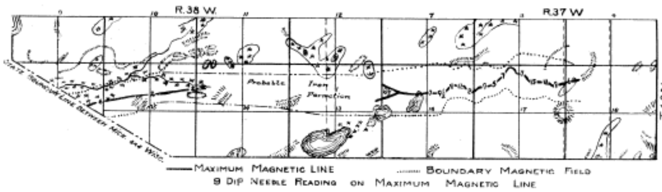


Figure 9. Magnetic belt in T. 43 N., R. 37 W., and T. 43 N., R. 38 W.

In township 45 N., R. 39 W., extending in an E.-W. direction just south of Watersmeet is another magnetic belt. In the north part of this township are outcrops of acid gneisses which are probably Archean. It is not known how far south in this township these rocks extend owing to lack of exposures but the south edge is undoubtedly north of the Watersmeet magnetic belt. This belt is in all probability underlain by iron formation, whether of Archean or later age is not known. It extends westward beyond the point shown on the plat where it was dropped at the close of the 1911 field season.

Further work planned for the season of 1912 will throw more light on the structural conditions here discussed but enough is already known to demonstrate that there is no direct connection between the Gogebic and the Iron River districts. The iron bearing series of the latter if continuous westward, which is a probability, passes south of the Archean mass which limits the Gogebic district on the south. Further work west of Watersmeet and southward to the state line is expected to reveal magnetic lines indicating the probable presence of iron formation and a continuance of the westward trend of the structures discussed above.

ORE RESERVES.

The development work of the last few years has shown two important and striking facts bearing on the future of this district, viz., (1) the ore bearing formation is exceedingly rich, i. e., the ratio of the volume of known ore to known iron formation is relatively high and (2) ore reserves have already mounted to a high figure. The Iron River district has one of the great ore reserves of the state if not actually the largest. The following table is taken from the report of J. R. Finlay to the State Tax Commission, 1911.

ORE RESERVES, IRON RIVER DISTRICT, 1911.

	Reported in sight above bottom level.	Total tonnage expected by J. R. Finlay.
Osana (James)	520,000	2,000,000
Chatham	43,000	100,000
Hiawatha	254,993	1,000,000
Baker & Tully	3,500,000	3,500,000
Dober (Riverton)	713,000	1,700,000
Baltic	460,000	3,000,000
Fogarty		
Caspian	3,505,500	10,000,000
Youngs	250,000	1,000,000
Zimmerman	1,000,000	1,000,000
Berkshire	563,000	1,000,000
Davidson	2,000,000	2,000,000
Wauseca	40,000	1,000,000
Chicagon	390,305	600,000
Michael Expl	1,000,000	1,000,000
Blair Expl	372,259	1,400,000
Houlihan	578,000	5,000,000
Rogers	349,306	2,500,000
Donahue	371,437	800,000
McGovern	258,413	350,000
Bates	....	400,000
Wickwire	....	40,000
Erickson	....	732,000
N. Y. State Steel	....	2,000,000
	10,169,213	42,122,000

The above estimates bring out the striking fact that this district has an expected tonnage in mines and explorations of 7 times the total shipments and furthermore that 15,822,000 tons or over 37% of the reserves is in properties which have not reached the producing stage.[9]

RECENT DEVELOPMENTS.

In 1910 attention was called to a possible southwestward extension of the iron formation through sections 15, 16 and 17, T. 42 N., R. 34 W. Since that date exploration has not been active on this indicated extension.

Proceeding northwestward important developments have been made at the Zimmerman Mine. The management here who formerly were dependent for the small output of the mine on small irregular ore bodies has succeeded in locating on the 4th level what bids fair to be a body of considerable proportions. The ore lies in a syncline of the drag fold type pitching northeast and slightly overturned toward the southwest. The ore extends upward from the 4th level to the surface. Its downward extension has not been determined, but ore is known at 600 feet in depth. In its present state of development this body is estimated to contain not less than 1,000,000 tons.

At the Baltic, Youngs and the Fogarty properties, we have to record no important recent development. The Baltic is developed to the seventh level 553' below collar of No. 2 shaft. The reserves above this level are still nearly half the total shipments from the mine with promise of substantial tonnage below this level. The Fogarty is developed to the third level at a depth of 260'. The mine was closed for over a year prior to May 15, 1911. The mine can produce steadily a moderate tonnage, which is also true of the Youngs mine adjacent to it on the south.

The Berkshire Mine has developed levels at 165, 265 and 365 feet. The strike of the ore body is eastward with the iron formation. The pitch is apparently also eastward, particularly in the west end of the mine where the ore is thrown eastward 160 feet in a vertical distance of 100 feet. The ore lies on a black slate wall dipping south at a high angle to the second level and thence downward vertical. The formation in the east end of the mine is swinging northward. The mine is young and the reserves already known are hardly more than opened up.

Adjacent to the Berkshire on the east is the Corry exploration which was drilled with encouraging results by the Verona Mining Co. It has been taken over by the Michigan Mining Co.,[10] who are conducting development work through a vertical shaft near the east central side of the property.

At the Caspian Mine, developments have not proceeded beyond the 3rd level 292 feet below surface. The area of developed ore on this level is 377,000 sq. feet. The ore body is by far the largest in the district and bids fair to development into one of the great deposits of the Lake Superior region.

North of the Caspian is the Tully property, which has now reached a producing stage. Drilling on the Tully has shown a large tonnage of ore. The ore from the Baker, adjacent to the Tully on the east, will be hoisted through the Tully shaft. The Baker was closed in June of 1911, owing to a refusal of the fee owners to allow operators to hoist Tully ore through the Baker shaft.

The Verona Mining Co. after several years of exploration has developed a very promising ore body on the Barrass-Houlihan property. The ore body lies in the middle east side of the N. W. ¼ of the S. E. ¼ of Sec. 36, 43 N., 35 W. It is partially developed on the first level only where it has dimensions of at least 450 by 200 feet, second only to the Caspian in area of developed ore. This property looks like the beginning of a very large mine.

The Brule Mining Company has added a considerable tonnage to the reserves of the Chatham Mine by taking over an option on the S. E. ¼ of the N. E. ¼ of Sec. 35, T. 43 N., R. 35 W. The ore body was located at depth in the south part of this description by the Cleveland Cliffs Iron Co. in 1909. This ore will be mined through the Chatham shaft.

Explorations conducted by W. H. Selden in the summer of 1911 in the N. E. ¼ of the S. E. ¼ of Sec. 34, T. 34 N., E. 35 W. known as the Manhattan, resulted in the discovery of an ore body, the dimensions of which are not yet known. The property has been leased by the Wickwire Mining Co. and a small shipment of ore was made in the fall of 1911. Exploration and development work is going rapidly forward. The ore body is on a belt of iron formation which strikes north of west into the middle of section 34, and in the opposite direction swings apparently southeast and then northeast into the North Hiawatha property where exploratory work was conducted by Mr. Selden in 1911.

North of Iron River very important developments have been made in what is known as the James belt. On the Osana (James) property an ore body of very considerable dimensions has been opened on the 4th level near the west end of the mine. The workings extend to within 200 feet of the east line of the adjacent Davidson No. 1 mine, formerly known as the Gleason. On the latter property the New York State Steel Co. is developing an ore body of considerable dimensions and north of it on the southern part of the S. E. ¼ of the S-. W. ¼ of Sec. 14, the Jones-Laughlin interests have developed a large tonnage by drilling. The ore here seems to extend eastward into Davidson No. 2 and westward across the S. E. corner of S. W. ¼ of the S. W. ¼ of the section where a small tonnage of ore has been shown by exploration conducted by the Wickwire Mining Co. The ore formation continues apparently southwestward and westward across the Donahue and McGovern leases of the Munroe Mining Co., into the middle of the W. ¼ of the N. E. ¼ of Section 22 where the Iron River Ore Co. is reported to have encountered ore in drilling in the fall of 1911. This latter reported discovery I have, however, not verified. The results of exploration on the James belt during the past two years indicates that it contains a large tonnage of marketable ore. Developments are being rapidly pushed on the Davidson No. 1 and Davidson No. 2 and the Jones-Laughlin property, but steps have not yet been taken to open the deposits known to exist westward on this belt. From the Osana (James) mine the belt extends east into the Spies exploration.

South of the James belt and striking about parallel to it through the middle of section 23 is an ore bearing formation on which the Mineral Mining Company has opened a very promising exploration known as the Wauseca, formerly the Konwinski. A considerable tonnage of ore has already been opened and the prospects are so favorable as to lead Mr. J. R. Finlay to place the expected tonnage at one million. The iron formation apparently dips steeply to the south between slate walls. Drilling east and south of the Wauseca location by the Republic Iron and Steel Co. is reported to have shown promising results and the property has been leased for mining.

From the Osana (James) Mine the ore-bearing belt extends east into the Spies exploration in the N. W. ¼ of the N. W. ¼of Sec. 24, and possibly eastward across the north part of this section to the Hall exploration of the Bates Mining Co. in the N. ½ of the N. W. ¼ of Sec. 19, 43 N., 34 W. The latter property has been explored by drilling and shaft sinking is now in progress.

The ore-bearing belt extending diagonally northeastward through the center of Sec. 29 and into the S. W. ¼ of Sec. 21, T. 43 N., R. 34 W. will be first opened on the Rogers location (N. E. ¼ of Sec. 29) by the Munro Mining Co. The sinking of the Rogers concrete drop shaft during the summer of 1911 was a notable piece of construction work, the first of its kind to be undertaken in this district. Following the successful experience of the Cleveland Cliffs Iron Company in dropping concrete shafts through deep, wet overburden in the Gwinn district, the Munro Mining Co. in 1911 introduced the first concrete drop shaft in the Iron River district. The shaft was started in February and completed in July, the work being done under contract by the Foundation Company of New York. The shaft was dropped through 140 feet of glacial drift. It is circular, 29 feet in diameter with rectangular compartment 16½ ft. by 11 ft., divided into pipe and ladder way, cage road, and a double skip road. The main advantages of the concrete shaft are its dryness, stability, and permanency. It is expected that similar conditions on other undeveloped properties will increase the number of concrete shafts in the Iron River district.

The Chicago Mine in the N. W. ¼ of the N. E. ¼ of Sec. 26, 43-34 which was the scene of one of the earliest explorations in the Iron River district, after a long period of persistent exploration by the Munro Mining Company, has been brought to a producing stage. The first shipments from this mine were sent out in the summer of 1911 over the recently completed spur of the Chicago and Northwestern Railroad from the main line about two miles east of Saunders. The strike of the ore formation in the Chicagon mine is about N. E. and S. W. The formation lies on a black slate wall, dipping S. W. at an angle of about 70 degrees. Black slate also occurs on the hanging walls. As measured on a cross section at a depth of 480 feet the iron formation is between 400 and 500 feet thick, making no allowance for folding. The ore body, from which shipments are being made, has been opened up on the 5th or 500 foot level. In the development of the body thus far, reserves totaling in the neighborhood of 400,000 tons are known to exist above this level.

It is thought probable that the ore bearing formation of the Chicagon Mine is at the same horizon as that of the Rogers Mine and may possibly be connected directly with the latter through the S. ½ of Secs. 21, 22 and 23. Some drilling is being done along this hypothetical line by the Cleveland Cliffs Iron Co., but results are not yet available for publication.

In the above paragraphs there has been outlined the more important developments which have been made in the last couple of years. Stagnation in the iron market during 1911 had no appreciable effect on exploratory activity in the Iron River district and from all indications the work of exploration will go steadily forward for some time to come. A large number of strong competing interests have secured a foothold in the district. Notwithstanding, the difficulties inherent in prospecting a drift covered field, the Iron River district offers in the proved richness of the ore bearing formation and the successful outcome of many recent operations, one of the most attractive areas for exploration in the Lake Superior region.

[2]Thomas Conlin and P. O'Brien. Lake Sup. Min. Inst. Vol. 16, p. 7, 1911. See also Proceedings of the Lake Sup. Inst. Min. Eng. for 1905.

[3]Monograph 46 U. S. Geological Survey.

[4]State Geologist of Wisconsin.

[6]Monograph 52, U. S. Geological Survey.

[7]Publication 3. Geological Series 2, Mich. Geol. Sur. 1910. Monograph 52, U. S. Geological Survey, 1911.

[8]Publication 3, Michigan Geological Survey.

[9]The Chicagon shipped in 1911.

[10]The Michigan Mining Co. was recently merged with the Iron County Steel Co.

GOGEBIG DISTRICT.

Location and Extent

The Gogebic iron district extends from Lake Gogebic westward to the Montreal River and is prolonged southwestward in Wisconsin to near Lake Numakagon under the name of Penokee range. Its total length is about eighty miles. In earlier years the name Agogebic was applied to the Michigan portion. In contrast to the history of other iron ranges the Gogebic was known and geologically mapped prior to the opening of ore deposits. The simplicity of rock structure and succession of strata combined with the topographic prominence of the range and the magnetism of the iron formation made possible early accurate geologic mapping. No ore discoveries have been made outside the limits of the iron formation thus early determined.

The earlier explorations were made on the western (Wisconsin) end of the range on the more highly magnetic and better exposed parts of the iron formation. The years immediately following the opening of the range in 1884 were marked by a frenzy of speculation. The companies formed in 1886 alone had a total capitalization of above $1,000,000,000.00.[11] In the crash that followed in 1887 the small investor was squeezed out, but some of the stronger companies survived and formed a neucleus which kept the work of exploration and development moving while business conditions were being readjusted. Despite the collapse of the speculative craze the production rose steadily from 1884, reaching a mark in 1892 that was not reattained until a decade later, 1902. The production curve is plotted in Fig. 11.

The district is served by the Duluth, South Shore and Atlantic Ry., the Wisconsin Central which crossed the range at Penokee Gap in 1873, extending a branch to the center of the district in 1887, and the Chicago and Northwestern Ry. which reached Ironwood from the

Menominee Range in 1882 and made connections with Ashland in 1885.

The Ore Deposits: The ore deposits are confined to the central part of the range extending from near Iron Belt in Wisconsin to Sunday Lake in Michigan, though ore is known on Secs. 15 and 21, T. 47 N., R. 43 W. west of Gogebic Lake. Up to 1910 Michigan had produced about 84% of the total output.

The important factors affecting the formation of the ore deposits are (1) the steeply inclined position of the iron formation, which limits the exposed part to a belt not greatly in excess of its thickness and favors great vertical component for the ore bodies compared to horizontal section. The ore deposits occupy only about 1 per cent of the area of the exposed iron formation.[12] (2) The underlying impervious quartzite dipping northward forms the foot-wall of the majority of the ore bodies and in many cases forms with (3) impervious basic dikes, which cut the bedding of the Huronian series at an average 90° angle, natural troughs, pitching usually gently eastward but in some cases westward, carrying the great ore deposits of the district. The ore deposits are generally best developed in the troughs thus formed extending upward along either or both limbs of the trough and following it downward along the pitch. The number of such pitching troughs on a given cross section is limited only by the number of intersecting dikes, and sections through many properties exhibit several ore bodies lying one above another each bottomed in a trough formed by the intersection of a dike with the footwall quartzite. The dikes vary up to about a hundred feet in thickness. (4) Interbedded slate or quartzite may function as a footwall carrying ore bodies in horizons which are far above the underlying Palms quartzite. (5) Minor structures such as bedding, brecciation and faulting serve as guides to downward moving water, and are thus favorable to secondary concentration. Some or all of these factors are operative in every instance in localizing ore bodies and in some cases are apparently alone adequate to induce alteration to ore. (6) Certain horizons in particular places were originally above average richness requiring less concentration to form ore bodies. This factor is believed to have been important in those places where ore bodies exist in the absence of structural conditions particularly inducive to secondary concentration, as at the Mikado, Brotherton and Sunday Lake mines.[13]

DEVELOPMENT.

As stated above no ore has been found outside the limits of the Ironwood formation as mapped prior to 1884. Exploratory work on the Gogebic Range is therefore not of necessity first directed toward locating the iron bearing rocks as in some other districts particularly the Iron River, Crystal Falls, and Gwinn areas but proceeds more directly to the opening of promising parts of the ore bearing formation. The methods employed elsewhere are used on the Gogebic but diamond drilling is carried on to less extent. In the working properties much attention has been directed to exploration at greater depths following the lead of Mr. J. R. Thompson whose persistent efforts revealed at the Newport, a large body of high grade ore at a depth of 2,000 feet and over. The proved occurrence of ore at great depth will prolong indefinitely the life of many properties on the Gogebic range. Whereas only a few years ago there was considerable apprehension among geologists and engineers regarding the existence of rich iron ores at anything over moderate depths, there is now a strong presumption that ores will be found at depths greater than that of the Newport deposit, possibly to the lower limits of profitable mining.

ORE RESERVES.

The tonnage of ore reserves reported to the Michigan State Tax Commission in 1911 is given below:

ORE RESERVES, GOGEBIC RANGE, 1911.

	Reported in sight by company.	Total tonnage expected. Estimates by J. R. Finlay.
Ashland	197,000	200,000
Norrie-Aurora	9,361,500	18,000,000
Newport	5,475,000	16,000,000
Puritan	50,000	100,000
Ironton	130,000	500,000
Yale	....	1,000,000
Colby	815,800	1,500,000
Tilden	404,500	1,000,000
Anvil and Palms	379,000	1,000,000
Eureka	65,000	200,000
Asteroid	10,000	....
Mikado	20,000	500,000
Chicago	184,000	500,000
Brotherton	995,000	1,000,000
Sunday Lake	150,000	1,500,000
Castile	1,000	....
Total	17,338,800	43,000,000

[11]Mon. 52, U. S. Geological Survey.

[12]Mon. 52, U. S. Geological Survey, p. 235.

[13]Mon. 52, United States Geological Survey.

MARQUETTE RANGE.

The Marquette district is the oldest of the iron districts of the Lake Superior region. It had been producing ore for 24 years prior to the opening of the Menominee district in 1872. The first discovery of iron ore in the Marquette district and the Lake Superior Region was made in 1844 at the site of the old Jackson mine at Negaunee by a U. S. land surveying party under charge of W. A. Burt who was working under Dr. Douglass Houghton, the first state geologist of Michigan. Lack of space forbids a sketching of the long and interesting history of the Marquette district. It is interesting to note that a large number of the important mines now worked in the Marquette district were opened prior to 1872, although very important discoveries have been made since that time, particularly in recent years.

RECENT DEVELOPMENTS.

The Marquette district, which has produced iron ore since 1848 or for 03 years, and in this time has sent to market 93,749,928 tons (to 1911) has an available estimated reserve of 75,977,006 tons (1911) of marketable ore or 80% of total shipments. There is more ore in sight today than ever before, a fact which illustrates in striking manner the relative permanency of the iron mining industry. Recent deep drilling in bottom horizons of the Negaunee formation "suggests that the beds of this horizon at great depths may ultimately be found to carry a larger tonnage of ore than those of any of the other horizons,"[14] a matter of transcendant importance to the future of the district. On the Marquette as well as in the Gogebic district development at great depth has changed what was formerly a hope into a practical certainty, viz., that deeply buried portions of the iron formation are ore-bearing and are likely to be fully as productive as the shallower parts.

The area underlain by the iron-bearing formations has long been known and appears on accurate maps of the U. S. Geological Survey. Explorers may therefore proceed to the opening of promising parts of the iron formation without necessity of first locating the formation itself as is necessary in the drift covered and less accurately mapped areas. In recent years there have been relatively fewer new explorations on the Marquette range than in the Crystal Palls and Iron River districts. This is not surprising in an area where the data of many years has thrown more light on the ore bearing possibilities of different localities. In other words, exploration on the Marquette range does not now of necessity proceed in many cases blindly but on the contrary with considerable assurance regarding the geological conditions expected to prevail. The stronger companies which operate in the district are well fortified with reserve tonnage and land holdings and in contrast with the conditions in the Crystal Falls and Iron River districts, in the main producing localities have neither the same necessity nor the opportunity to compete for new acquisitions. The field is an old one and partition of interests was practically established long ago.

Important construction work has been under way by the Cleveland Cliffs Iron Co. A new concrete shaft was sealed to ledge at the Maas mine in September, 1911. The concrete work is circular, 200 feet deep with rectangular opening 11 ft. 2 in. by 15 ft. 2 in. inside including a pipe and ladder way, one cage and two skip roads. A similar shaft was constructed at the Negaunee mine. The most important recent work undertaken by this company, however, is the installation of an hydro-electric power system, the largest project of its kind ever undertaken in the Michigan mining regions.

The Carp river is to be harnessed through a plant of two 4,000 H. P. units equipped for 60,000 volts, located just opposite the state prison near Marquette, driven by a fall of 600 feet on a 25% grade from a stand pipe one-half mile distant on the top of Mt. Mesnard. The dam is four miles up stream from the power house. It is 50' wide at the base and 120' in length. From the dam the water will be conveyed through a 22,000' line of pipe 66" in diameter, 12,000 feet of steel and 10,000' of Washington fir staves. The power will be conveyed from the generating station over a double circuit transmission line some 36 miles long to the company's mines at North Lake, Ishpeming, Negaunee and the Gwinn district. The cost of the installation is estimated at about $1,000,000.00.

Four new mines should be added to the producing list in 1912, viz., the Maitland, Morris (North Lake No. 1), Lloyd (North Lake No. 2) and the Chase (Barnes). During 1910 and 1911 work has gone steadily forward at the three latter properties. Steel head-frames have been erected and the ore deposits partially opened up. The Maitland is a new property of the Volunteer Ore Co. located at the east end of Palmer Lake. The shaft is down about 300 feet and a soft ore body of high grade partially developed.

Another event of importance is the installation of the Ardis furnace at the old Kloman mine for the treatment of low grade ores by the Jones Step Process. The problem of the utilization of low grade ores is an important one and we have, therefore, chosen to give separate and detailed treatment of the Jones Step Process in a separate chapter.

ORE RESERVES.

The tonnage of ore reserves on the Marquette range as reported by J. R. Finlay to the Michigan State Tax Commission is given below.

ORE RESERVES, MARQUETTE DISTRICT, 1911.

Mine.	Reported in sight above bottom level.	Total tonnage expected by J. R. Finlay.
Lillie	72,651	72,651
Cambria (Old Hartford)	825,000	825,000
Mary Charlotte No. 1 and No. 2	1,500,000	2,775,000
Breitung Hematite No. 1 and No. 2	250,000	2,000,000
Lake Angeline-Mitchell	430,000	475,000
Rolling Mill	1,152,177	1,500,000
Lake	3,707,110	3,707,000
Negaunee	13,635,200	13,635,000
Salisbury	584,000	584,000
Mass	9,662,400	9,662,000
Lake Superior Soft Ore	2,250,000	4,000,000
Queen	1,893,000	1,900,000
Race Course	....	1,500,000
Lucky Star	....	4,000,000
Harvey Lots	....	4,000,000
North Range	....	1,510,000
Republic	1,358,000	2,000,000
Washington	....	....
Barron	310,000	432,000
Franklin	....	....
American Boston (not reported)	....	500,000
Volunteer	30,000	150,000
Lake Superior Hard Ore	1,470,000	2,270,000
Section 16	5,311,355	9,446,355
Champion	1,625,000	2,825,000
Cliff Shaft	2,167,000	2,500,000
Moro	50,000	50,000
North Lake 6-47-27	....	594,000
Imperial	1,500,000	1,500,000
Ohio	117,100	317,000
Portland	247,085	247,000
Total	50,147,078	75,977,006

GWINN (SWANZY) DISTRICT.

The Gwinn district lies south of the Marquette range in T. 45 N., R. 25 W. It is served by the Chicago and Northwestern Ry. and the Munising Ry. The district has produced more or less steadily from the old Swanzy (Princeton) Mine since 1872. Development work of the last decade has brought the district rapidly into prominence. The Stephenson and Austin made first shipments in 1907, the Stegmiller in 1909. The Smith began hoisting in September, 1911, and concrete shafts are sealed to ledge on the Kidder and Northwestern. The district is controlled with the exception of the

Stegmiller mine which is operated by the Oliver Iron Mining Co., by the Cleveland Cliffs Iron Co., by whom active exploration has been conducted since 1902. Electric power will be supplied by the Cleveland Cliffs Iron Co. transmission line from their plant on Carp River near Marquette.

Probably the most attractive mining town in the Lake Superior Region is the village of Gwinn, planned and built by the Cleveland Cliffs Iron Co. The only natural advantage is its situation on the Escanaba river which affords good drainage and a sewage outlet. The village is laid out on a beautiful plan with ample parks. A fine commodious school building, an excellent club house for employes of the company and a good hotel are noteworthy features, while the general cleanliness and cheerfulness of appearance of both business and residence portions of the village is indeed refreshing to the visitor as it must be to the residents. The company, whose skill, energy and foresight has created an industry which supports a growing community with modern provisions for human comfort and sanitation where lately was a jack pine sand plain should be commended and congratulated.

GEOLOGY.

The Gwinn district forms a southeastward pitching synclinorium of Upper Huronian rocks about 2 miles long and ½ to ¾ of a mile wide, widening to the southeast where the structure is lost beneath, deep overburden. In other directions the district is surrounded by hills of Archean granite.

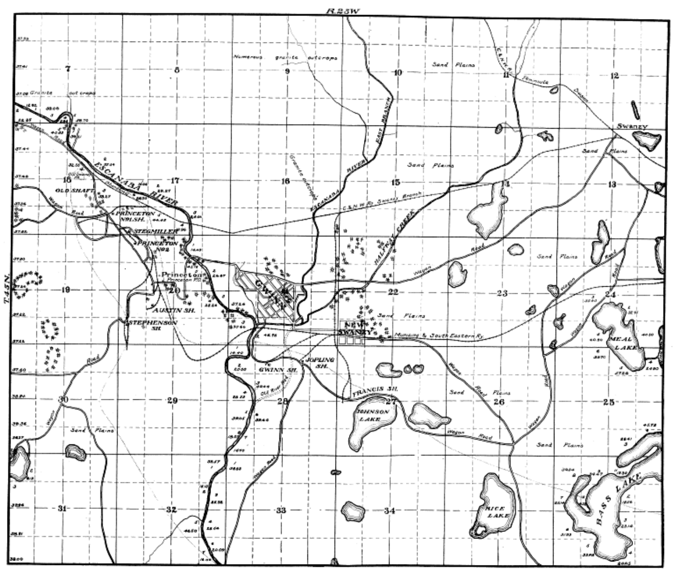


Figure 10. Map of the Gwinn District compiled from plats of the Cleveland Cliffs Iron Co. and the Oliver Mining Co.

The Upper Huronian rocks lie unconformably on the Archean granite and comprise two distinct formations, viz-., the Goodrich quartzite, which at the base is a recomposed granite or arkose grading upward through quartzite and quartz slate into the Bijiki iron-bearing member, and the Michigamme slate series in which the Bijiki formation is included. The Goodrich quartzite is absent in places thus bringing the slate or iron formation into contact with the underlying granite.

Flat lying Paleozoic limestones and sandstones overlap to the east, the older formations of the Gwinn district (See fig. 10.)

ORE RESERVES.

The ore reserves of the district as reported to the State Tax Commission by J. B. Finlay in 1911 are given below:

ORE RESERVES, GWINN DISTRICT, 1911.

Mine.	Reported in sight above bottom level.	Total tonnage expected by J. B. Finlay.
Stegmiller	240,000	266,000
Princeton No. 1 and No. 2	1,157,317	1,057,000
Austin	503,774	503,774
Stephenson	780,646	780,646
Smith	952,727	952,727
Sec. 19, 45-25 N. E. ¼ of N. E. ¼		54,143
Sec. -25 lots 2 and 3		523,339
Sec. 27, 45-25 S. W. ¼ and S. W. ¼ of N. W. ¼		345,203
Kidder		646,071
Sec. 29, 45-25 N. ½ of N. W. ¼		246,800
Sec. 35, 45-25 S. E. ¼ of S. E. ¼		453,425
Sec. 35, 45-25		916,130
	3,640,464	6,746,158

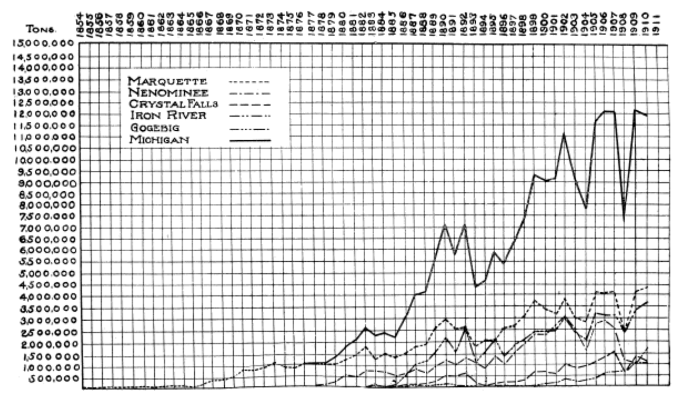


Figure 11. Production curves for Michigan iron ranges.

[14]Mon. 52, U. S. Geological Survey.

PIG IRON INDUSTRY IN MICHIGAN.

BY ALBERT E. WHITE.[1]

CONTENTS.

CHAPTER I. INTRODUCTION.

PRODUCTION.

Because of the vast iron ore wealth of Michigan, there is no question before the people of the State today of greater interest than that pertaining to the use of these selfsame iron ores. Hitherto it has been true that the majority of ores mined in the State have been shipped to points outside of the State's domains for smelting. This tendency has been due to several causes. Important among these are the facts that there are points such as those existing in Chicago, Cleveland, Buffalo, Pittsburg, etc., which are nearer the points of actual steel consumption than any localities found in Michigan. It is of course true that it is cheaper to ship a raw material such as ore than it is to ship a finished product such as steel. Combined with this reason there is the further fact that the localities mentioned above, particularly Pittsburg, are favored by being near the coal fields, and coal is a product of prime importance in the production of iron or steel. This feature may be noted by the fact that in the production of one ton of coke pig iron—and over 90% of our pig iron made today is smelted with coke—approximately 2,200 pounds of coke are required. Converting this figure into coal terms it is noted that approximately 3,400 pounds of coal are required for one ton of pig iron, and for the production of steel from the raw ore from 4,000 to 5,000 pounds of coal are required for a ton of steel produced. For these reasons, the one because of location and the other because of fuel supply, and because Michigan lacks both of these essentials, it will be true that Michigan will never be a large pig iron producing center. This fact holds particularly true with reference to the production of coke pig iron in Michigan, and it will probably be many years before any further coke blast furnaces will be built other than those which are already located in Detroit at the plant . of the Detroit Iron and Steel Company and the plant of the Detroit Furnace Company.

The standing of Michigan as a charcoal pig iron producing center is an entirely different question, and assumes an entirely different aspect for at the present writing she makes more charcoal pig iron than all of the other states combined. This condition is due to the fact that she has her rich ore mines and she likewise has, especially in the Northern Peninsula, large tracts of woodland which are capable of producing large quantities of charcoal for many years to come. It is true, of course, that the forests in Michigan are gradually being denuded, but it is estimated that there is enough wood in the State at the present time to keep the present number of blast furnaces in operation at their present rate for a period of fifty years. By proper conservation and growth of new trees it could very likely be true that Michigan could produce her present yearly output of charcoal pig iron for almost an indefinite period.

A conception of the importance of this industry should be gleaned from an examination of the following table which shows the yearly production of pig iron in the United States from 1854 to the present time and the part Michigan has played in this production since 1872.

PIG IRON PRODUCTION.

Year.	Michigan production.	U. S. Production.			Total.
		Charcoal.	Anthracite.	Bituminous.	
1854		342,298	339,435	54,485	736,218
1855		339,922	381,866	62,390	784,178
1856		370,470	443,113	69,554	883,137
1857		330,321	390,385	77,451	798,157
1858		285,313	361,430	58,351	705,094
1859		284,041	471,745	84,841	840,627
1860		278,331	519,211	122,228	919,770
1861		195,278	409,229	127,037	731,544
1862		186,660	470,315	130,687	787,662
1863		212,005	577,638	157,961	947,604
1864		241,853	684,018	210,125	1,135,996
1865		262,342	479,558	189,682	931,582
1866		332,580	749,367	268,396	1,350,343
1867		344,341	798,638	318,647	1,461,626
1868		370,000	893,000	340,000	1,603,000
1869		392,150	971,150	553,341	1,916,641
1870		365,000	930,000	570,000	1,865,000
1871		385,000	956,608	570,000	1,911,608
1872	86,840	500,587	1,369,812	984,159	2,854,558
1873	113,975	577,620	1,312,754	977,904	2,868,278
1874	128,965	576,557	1,202,144	910,712	2,689,413
1875	101,805	410,990	908,046	947,545	2,266,581
1876	82,477	308,649	794,578	990,009	2,093,236
1877	75,216	317,843	934,797	1,061,945	2,314,585
1878	70,853	293,399	1,092,870	1,191,092	2,577,361
1879	101,539	358,873	1,273,024	1,438,978	3,070,875
1880	154,424	537,558	1,807,651	1,950,025	4,295,414
1881	187,043	638,838	1,734,462	2,268,264	4,641,564
1882	210,195	697,906	2,042,138	2,438,078	5,178,122
1883	173,185	571,726	1,885,596	2,689,650	5,146,972
1884	172,834	458,418	1,586,453	2,544,742	4,589,613
1885	143,121	399,844	1,454,390	2,675,635	4,529,869
1886	190,734	459,557	2,099,597	3,806,174	6,365,328
1887	190,663	529,457	1,901,256	2,957,232	6,387,945
1888	190,403	598,789	1,925,729	4,743,989	7,268,507
1889	191,395	644,300	1,920,354	5,952,414	8,517,068
1890	230,769	703,522	2,448,781	7,154,725	10,307,028
1891	213,145	570,964	1,866,108	5,836,798	8,279,870
1892	184,421	537,621	1,797,113	6,822,266	9,157,000
1893	117,538	386,789	1,347,529	5,390,184	7,124,502
1894	95,171	222,422	914,742	5,520,224	6,657,388
1895	91,222	225,341	1,270,899	7,950,068	9,446,308
1896	149,511	310,244	1,146,412	7,166,471	8,623,127
1897	132,578	255,211	932,777	8,464,692	9,652,680
1898	147,640	296,750	1,203,273	10,273,911	11,773,934
1899	134,443	284,766	1,599,552	11,736,385	13,620,703
1900	163,712	299,124	1,841,857	12,253,818	13,789,242
1901	170,762	390,147	1,712,527	13,782,386	15,878,354
1902	155,213	378,504	1,115,247	16,315,891	17,821,307
1903	244,709	504,757	1,911,347	15,592,221	18,009,252
1904	233,225	337,529	1,228,140	14,931,364	16,497,033
1905	288,704	352,928	*1,300,000	*21,339,452	22,992,380
1906	369,456	433,007	1,305,094	23,313,498	25,307,191
1907	436,507	437,397	1,371,554	23,972,410	25,781,361
1908	348,096	249,146	355,009	15,331,865	15,936,018
1909	964,289	376,003	698,431	24,721,037	25,795,471
1910	1,250,103	394,377	649,082	26,255,086	27,298,545
1911	542,193	160,847	149,227	11,355,722	11,665,796

*Estimated.

Note:—These figures may not altogether tally because great difficulty was encountred in preparing the table; for at best the figures had to be obtained from many and various sources.

Michigan's production from 1906 includes the production in Indiana also. To 1906 the production is altogether charcoal. Michigan's production for 1903, 1904 and 1905 is not quite complete as it does not have the tonnage of coke pig iron made in the State during those years.

1911's figures are for the half year from January 1st to July 1st.

The figures up to 1891 are in net tons. Beginning with 1891 the figures are in gross tons.

[1]Instructor in Chemical Engineering, University of Michigan.

HISTORY AND DEVELOPMENT OF THE INDUSTRY.

No notice of Michigan as a pig iron producing center was taken to any marked extent until about 1840. At that time it was reported that there were fifteen blast furnaces in the State. Many of these were doubtless forges and as such could not be credited as being true blast furnaces. They were all in the southern part of the State. From 1840 to 1850 Michigan as an iron center suffered a decline, but from 1850 to 1860 considerable progress took place in the industry. This progress consisted in the building of three new furnaces for the purpose of smelting the bog ores found in the southern part of the State and likewise in developments that took place in the Northern Peninsula. The first pig iron made in the Lake Superior region was in 1858 by Stephen E. Gay who converted a forge into a miniature blast furnace. The first regular furnace erected in this region, however, was that built by the Pioneer Iron Company in the present city of Negaunee, convenient to the well known Jackson mine. This company, which is a subsidiary of the Cleveland Cliffs Iron Company, is still in active operation, and it has been manufacturing pig iron for a longer period than any corporation doing like work within the bounds of the State. While such progress as just noted was being made in the Northern Peninsula, slight development was made in the southern portion of the State, particularly near Detroit. In that region the Eureka furnace was built in 1855 by the Eureka Iron Company with Captain E. B. Ward as President; and a furnace at Detroit, known as the Detroit Furnace, was built in 1856 by the Lake Superior Iron Manufacturing Company, with George B. Russell as President. This latter furnace, if the writer is not mistaken, is the one at present owned by the Detroit Furnace Company, and up to the past few months has been in active operation, although for the past few years it has been using coke in place of charcoal as its metallurgical fuel. The Eureka Furnace has been one of the best known furnaces in the State and in its day has been one of the most successful of blast furnaces. The difficulty of getting ore to the furnace and the great difficulty it encountered, because of its location, in getting fuel at a reasonable cost, are the reasons why, after a long and successful operation, the furnace went out of blast.

From this time on, a minute study of the history of the pig iron industry in Michigan would, in reality, prove to be a long and probably tedious presentation of facts. Many furnaces have been built and after a short operation have either been sold to other parties, dismantled and taken elsewhere, or else completely shut down. (There has probably been less consolidation among the makers of charcoal pig iron than in any other branch of the iron and steel business. The writer knows of no definite attempt to unite the charcoal furnaces together under one strong head until the formation of the Lake Superior Iron and Chemical Company in 1910.) Such fluctuations and variations have largely been due, probably, to the lack of a sufficient supply of charcoal at any one place for a long period. It has proved more wise to either dismantle a plant or else move it to a fresh charcoal center when the supply of charcoal disappeared from the old location, than to bring charcoal to the plant from long distances. In other words, the policy has been to bring the furnace to the charcoal rather than the charcoal to the furnace.

Because of the above reasons, pig iron production in Michigan from 1870 to 1880 and from 1880 to 1890 sustained no great improvement. As regards quantity it is true that the State sent forth nearly as much pig iron as it ever had; in fact, for the most part, the quantity produced slightly increased although the percentage of increase was no greater than the percentage of increase throughout the country. For example, this State in 1880 ranked fourth as a pig iron producing center; in 1890 it had dropped to 8th place; and in 1900 it was still 8th; while in 1910 it was ranked as the 7th State, due largely to the output of the Detroit Iron and Steel Company's two coke furnaces at Detroit. It was from 1890 to 1900 that more changes of management took place than in any other period. The early part of the ten years was a period of almost continual depression, and pig iron manufacturers in Michigan suffered more financial embarrassment than they have in any of the other periods.

The last ten years have seen sort of a revolution regarding the manufacture of pig iron from charcoal. In the early days wood was cut and charcoal made from it without in any way considering the by-product values found in wood, such a wood alcohol, calcium acetate, etc. It had largely been a question of cutting wood, carbonizing it, and then smelting iron ore with it as a quick and efficient means of clearing ground and at the same time getting financial returns. In many cases the investment idea was emphasized more than the thought of clearing the ground. Such a condition encouraged men to go into the proposition to just as light an extent as possible, without giving any concern as to the future of the business. This attitude, of necessity, led to poor equipment, and an absence of all permanency. Because of these facts pig iron could be made with a high market but it could not be made at a profit with a low market.

The poor logic of this attitude was after a time realized and the companies that are in business today are doing all in their power to put the industry on a permanent footing. By means of charcoal and retort by-product kilns they are endeavoring to recover from the wood all the values possible. They are cutting the wood and developing new growths with a proper attitude toward conservation and they are equipping their furnaces with such mechanical appliances as will tend to materially reduce costs.

Up to 1903 the entire amount of pig iron made in Michigan was smelted with charcoal. For that reason everything which has been said in regard to the history of the industry in the preceding statements has related entirely to charcoal plants. In 1902 the Detroit Iron and Steel Company had its formation and in 1903 it put in blast a large merchant coke pig iron furnace in Detroit. This plant has been operated continuously since that time, with the addition in 1910 of another merchant coke furnace. Likewise in 1906 the Detroit Furnace changed hands, and since that time it has been producing coke pig iron.

With this brief resume we are taken down practically to the present writing. A tabulated list of the furnaces at present in operation or capable of being operated is presented, and a somewhat detailed statement with regard to each plant is also added.

BLAST FURNACES IN MICHIGAN.

Name of furnace.	Name of company.	Location of furnace.	Activity.	Type of fuel.	Activity of furnace.
Antrim	Antrim Iron Company	Antrim	In blast	Charcoal	115 tons
Cadillac	Mitchell-Diggins Iron Co	Cadillac	In blast	Charcoal	100 tons
Carp	Pioneer Iron Company	Near Marquette	Idle	Charcoal	50 tons
Chocolay	Lake Superior Iron & Chemical Co.	Harvey	Idle	Charcoal	70 tons
Detroit	Detroit Furnace Company	Detroit	Idle	Coke	75 tons
East Jordan	East Jordan Furnace Company	East Jordan	In blast	Charcoal	80 tons
Elk Rapids	Lake Superior Iron & Chemical Co.	Elk Rapids	Idle	Charcoal	110 tons
Gladstone	Pioneer Iron Company	Gladstone	In blast	Charcoal	
Manistique	Lake Superior Iron & Chemical Co.	Manistique	Idle	Charcoal	110 tons
Marquette	Pioneer Iron Company	Marquette	In blast	Charcoal	120 tons
Newberry	Lake Superior Iron & Chemical Co.	Newberry	Idle	Charcoal	80 tons
Pine Lake	Lake Superior Iron & Chemical Co.	Boyne City	In blast	Charcoal	110 tons
Spring Lake	Spring Lake Iron Company	Fruitport	Idle	Charcoal	75 tons
Stevenson	Stevenson Charcoal Iron Co.	Wells	Building	Charcoal	60 tons
Zug Island A	Detroit Iron & Steel Company	Detroit	In blast	Coke	300 tons
Zug Island B	Detroit Iron & Steel Company	Detroit	In blast	Coke	325 tons

DETAILS OF BLAST FURNACES IN MICHIGAN.

Name of furnace.	Lines of furnace.					Twyeres.		Stoves.			
	Heighth.	Hearth Depth.	Bosh Diam.	Hearth Diam.	Throat Diam.	No.	Size.	No.	Size. Heighth.	Size. Diam.	Kind.
Antrim	60′	6′	12′	6′	7′	8	4″	2			Durham pipe.
Cadillac	65′	6′	11′ 4″	7′ 8″	7′ 6″	5	4″	3	60′	16′	Kennedy Brick.
Carp	58′		10′								Durham Pipe.
Chocolay	40′		8′					2			Durham Pipe.
Detroit	62′	7′ 8″	12′ 6″	7′ 6″	7′ 4″	7	3½″	3			Durham Pipe.
East Jordan	60′	6′ 6″	10′	6′	6′	5	4½″	2	60′	16′	Three-pass Brick.
Elk Rapids	64′	6′ 3½″	12′ 6″	7′ 6″	7′			2			Durham Pipe.
Gladstone	60′		12′			5	5″	3	70′	16′	Roberts-Cowper Brick.
Manistique	59′ 6″	5′ 4″	12′ 6″	7′	7′ 6″			2			Durham Pipe.
Marquette	70′		13′					3			Roberts-Cowper Brick.
Newberry	60′	6′	12′	7′ 6″	7′ 6″	4	4″	2			Durham Pipe.
Pine Lake	62′ 9″	6′ 8″	12′	7′ 2″	6′ 6″			2			Two Pass Brick.
Spring Lake	50′		11′					2			Durham Pipe.
Stevenson	60′		10′					2			Two Pass Brick.
Zug Island A	78′	6′	18′ 8″	13′	12′ 6″	10	5″	4	83′	20′	Garrett-Cromwell Brick.
Zug Island B	80′	7′	18′ 6″	12′ 6″	12′ 6″	12	5″	4	85′	12′	Nelson-McKee Brick.

CHAPTER II. DETAILS REGARDING THE BLAST FURNACES IN MICHIGAN,

Because of the great diversity between charcoal pig iron and coke pig iron there will be made in this article no attempt to draw comparisons between the two. Each one will be treated independently and by itself. Each type of pig iron has its own place and there is little question but what a ready market will be found for the sale of charcoal pig iron if the manufacturers of this self same article are willing to place it on a competing basis as regards price, with that of coke pig iron.

Regarding the last point, such a condition is almost true at the present writing for the selling price of charcoal iron in Chicago today is but $16.50 a ton while the selling price of coke pig iron in the same center is $14.00 per ton.

That there can be but little profit in the manufacture of either product when the investment necessary for the business is considered and the amounts of off iron which are made of necessity no matter how carefully the smelting is watched, may be gleaned by studying the following cost sheets.

Charcoal pig iron.		Coke pig iron.	
Ore, 2.05 tons at $2.50	$5 13	2.05 at $2.50	$5 13
Charcoal or coke, 90 bu. at $0.06	5 40	1.1 at 4.50	4 95
Stone, .25 tons at $1.00	25	.5 at 1.00	50
Operating and repairs	2 50		1 25
Freight	1 50		
Cost per ton of pig iron at Chicago	$14 78		$11 83

Because of the diversity, however, each type of iron will be given its own respective place.

CHARCOAL FURNACES.

With the selling price of pig iron as it is at the present time there is absolutely no question but were the by-product values of wood disregarded there would be no manufacture of charcoal pig iron in Michigan today, for if there was, the industry would be carried out at a loss and such a condition could not long exist. Every charcoal plant operating today either owns its by-product recovery plant or else it is in such close union with a plant getting by-product values from wood as to be assured of a definite and regular supply of charcoal at a reasonable figure; the cost of the charcoal varying as the price of the charcoal pig iron varies.

There are two types of kilns extensively used in manufacturing charcoal. The one is a beehive kiln capable of containing from 60 to 90 cords of wood at a time, and producing approximately 45 bushels of charcoal per cord of wood. The operating cost for making charcoal is approximately 1½c per bushel and a kiln of this type will cost approximately $600.00. It takes 30 days to "turn" a kiln. By "turning" is meant the filling of the kiln, the carbonizing of the wood, the cooling of the wood and the discharging of the wood from the kilns. In a retort kiln, wood is placed on steel buggies or carriers which hold from 8 to 10 cords. The loaded buggy remains in the retort chamber for 24 hours, after which time the heat in the retort has driven out all the volatile matter and has carbonized the wood. The retorts are steel chambers 47’ long, 96" high and 78" wide. They are heated by the combustion of otherwise useless waste gases that come off from the carbonizing of the wood and likewise in emergencies they can be heated by the burning of wood. Combustion takes place in a chamber surrounding the retort. The flame does not hit the wood in the retort but heat is transmitted to the wood by radiation. This is directly the reverse of the action which takes in the beehive kiln where a certain quantity of the wood in the kiln is burned, solely for the purpose of giving enough heat for the carbonizing of the rest of the wood in the kilns.

Most all of the furnaces are hand filled, the one exception being Pioneer No. 2 Furnace at Marquette. Likewise in most all of the plants the stock house and stoves and storage bins are placed under shelter. This is primarily due to the fact that because of the cold, particularly with regard to the stoves, it has been found advisable to have them covered up, for in so doing a considerable loss of heat due to radiation is avoided.

The covering of the stock bins is to prevent the ore from freezing as much as possible. It has been found cheaper to cover up these stocks of ore than it has been to keep gangs of men busy all winter digging out the frozen ore. This can be done somewhat more handily than it can in the case of furnaces making larger tonnages of pig iron; for with charcoal furnaces a storage stock house capacity of from 60,000 to 75,000 tons is all that is necessary, while in some of the larger units that are making pig iron in the Pittsburg or Chicago districts storage capacities of from 750,000 to 1,500,000 is hardly more than adequate. Shelter storage bins for tonnages of this latter type is, of course, out of the question. It was interesting to note that the stoves of the Mitchell-Diggins Iron Company at Cadillac were unprotected, and Mr. Lamoureaux, the Superintendent of that plant, stated that he experienced no difficulty in getting what heat he wished from the stoves.

Throughout, all of the charcoal furnaces cast in sand. For the most part the tapping hole is hand plugged rather than with a Gunnell's gun.

ANTRIM IRON COMPANY.

The Antrim Iron Company was organized in Michigan in 1886 with a capital stock of $350,000.00. Its officers are W. Bernhardt, President; J. C. Holt, Vice President and Treasurer; H. J. Bennett, Secretary; and N. M. Langdon, Manager.

The furnace was built in 1883 or 1884 by Mr. Otis, who was financially backed by Mr. Cherry of Chicago. On the latter gentleman's failure in 1884-5 the plant went into the receiver's hands, with Mr. Bernhardt as receiver. Mr. Otis, however, was permitted to pull the furnace out of the hole. Mr. T. J. O'Brien was President of the Company from that time until he resigned to enter the United States diplomatic circles as Minister to Japan.

Regarding the furnace proper, it is 60' high and it has a 12' bosh; the diameter of the throat is 1' and of the hearth is 6', with a hearth depth of 6'. It is hand filled and is capable of producing 115 tons of pig iron per day; but because of dull market conditions but 80 tons of pig iron is being produced daily at the present writing. It has 8 twyeres, and the diameter of the blow pipes at the nozzle of these twyeres is 4 inches. The blast pressure varies from 5 pounds to 7½ pounds to the square inch; an increase in blast pressure of necessity implying an increase in pig iron production. About 6,500 cubic feet of air is blown into the furnace per minute, and an average of 91 bushels of charcoal is used per ton of pig produced.

There is one double Durham iron pipe stove which heats the blast up to about 900° F. There are 18 U-pipes in the stove. There is also a spare stove. The blast is furnished by one vertical Weimer blowing engine, with a piston displacement in the blowing tub of 72" x 48". There are 6-150 H. P. and 2-200 H. P. Wicks vertical water tube boilers. These are both gas fired with waste gases from the blast furnace and wood fired.

The charcoal is obtained from 56-55-cord beehive charcoal kilns, and 20-80 cord charcoal kilns of the same type. Wood alcohol and acetate of lime is secured from the volatile matter given forth in the carbonizing of the wood. Connected with the plant is a saw mill wherein the best of the lumber cut is sawed into shape and sold for building purposes.

EAST JORDAN FURNACE COMPANY.

The East Jordan Furnace Company was organized in Michigan, November 24, 1909, with a capital stock of $375,000.00. Its officers are Charles H. Schaffer, President; F. B. Baird, Vice President; and W. J. Ellson, Secretary and Treasurer. The furnace is located at East Jordan, Michigan, on the Detroit and Charlevoix, and East Jordan and Southern Railroads.

A large portion of the plant came from Principio, Maryland. A plant had at one time been in operation at that point making charcoal pig iron, but because of market conditions and the failure to have at hand a supply of charcoal it had to be abandoned. It was bought en masse by Michigan parties and moved to East Jordan.

The height of the furnace is 60' and the diameter of the bosh is 10'. The diameter of the throat is 6' and of the hearth is likewise 6'. The depth of the hearth is about 6' 6". The furnace is producing daily at the present time about 60 tons of pig iron. It could produce more, but because of the present dull market and because of lack of fuel, as the chemical plant from which the company derives its charcoal can give them but enough for 60 tons of pig iron per day, it is unable at present to give-a greater tonnage. The furnace is hand filled. It consumes approximately 93 bushels of charcoal per ton of pig. There are five twyeres, the nozzle diameter of the blowpipe being 4½".

Connected to the furnace are two 3-pass stoves, each one of which is 60' high and 16' in diameter. The blast is heated to from 950° F. to 1,100° F. Stoves are changed every 1½ hours. The blast pressure is 3½ to 4 pounds. The blast is furnished by a Weimer blowing engine which makes from 15 to 17 revolutions per minute. From 7,500 to 8,000 cubic feet of air is supplied to the furnace per minute. For generating power there are 6-250 H. P. water tube boilers of the Wicks type. Blast furnace gas and refuse from the saw mill is used as the boiler fuel.

The charcoal used in the furnace is obtained from the East Jordan Chemical Company. This company have 14-8-cord retort kilns and make the usual by-products from the wood consisting of wood alcohol and calcium acetate. The furnace plant is in no way connected with the chemical plant, but the chemical plant is under contract to supply to the furnace plant a definite amount of charcoal, and this feature assures the furnace company the supply of charcoal necessary for its operation.

LAKE SUPERIOR IRON AND CHEMICAL COMPANY.

The Lake Superior Iron and Chemical Company was organized in July, 1910, under the laws of the State of Michigan, with a capital stock of $10,000,000.00. Its present officers are John Royce, President; W. H. Matthews, Vice President and General Manager; L. F. Knowles, Secretary; and A. Van Oss, Treasurer. It is a consolidation of many of the charcoal plants scattered throughout Michigan, and it is putting many modern methods and practices into the manufacture of pig iron.

The company owns the Manistique furnace at Manistique, Michigan, the Newberry furnace at Newberry, Michigan, the Elk Rapids furnace at Elk Rapids, Michigan, the Pine Lake furnace at Boyne City, Michigan, the Chocolay furnace at Chocolay, Michigan, and the Hinkle furnace at Ashland, Wisconsin. With regard to the furnaces in Michigan but one, the Pine Lake stack, is operating at the present time. The Hinkle furnace is also operating but as its location is outside of the State it will not be treated or spoken of at further length in this article. The Manistique and Newberry and Elk Rapids furnaces will probably be blown in within the next few weeks, however. Extensive repairs and changes have been going on at these two plants and that fact for the most part accounts for their present idleness. The Chocolay furnace is so old and antiquated that it is extremely doubtful if it will ever again see further operation.

CHOCOLAY FURNACE.

The Chocolay furnace is an old stone stack formerly owned and operated by the old Lake Superior Iron and Chemical Company—now known as the Northern Iron and Chemical Company—and acquired in July, 1910, by the present Lake Superior Iron and Chemical Company. It formerly had an open top and boilers were placed on a fourth floor in order to more efficiently use the waste heat from the furnace. It has been owned by many different parties and it has been rebuilt and remodelled a great many times. From its early erection, however, it has proved to be a failure from a business standpoint. As soon as the present parties bought it they shut it down and it will not be operated until such a time as the price of pig iron rises to a point where a profit in its operation can be assured.

The stack itself is 40' high and has a bosh 8' in diameter. It is capable of producing 70 tons of pig iron per day. The blast is heated by means of two small Durham iron pipe stoves. The old blowing engine, has a piston displacement of 48” x 72" and makes from 11 to 13 revolutions per minute.

When operating it made car wheel and malleable pig iron, using charcoal as its fuel.

ELK RAPIDS FURNACE.

The Elk Rapids furnace, at present owned by The Lake Superior Iron and Chemical Company, is located on the Pere Marquette Railroad at Elk Rapids. Michigan. The furnace proper has been out of blast since early in the spring of 1911. Since that time, however. remodelling changes have been going on and it is very probable that the early spring will see the furnace in operation again.

The stack itself is 64' high and it has a 12' 6" bosh. The throat is 7’ in diameter and the hearth is 6' 3½" deep and 7' 6" in diameter. Connected to the furnace are two iron stoves, one is 18' x 28' and another 18' x 24'; each one has 21 pipes. There is one Weimer blowing engine having a capacity of 8,000 cubic feet per minute, also there is one old engine with a capacity of from 5,000 to 6,000 cubic feet per minute. Power is derived for the running of the blowing engines, pumps, etc., by four return type tubular boilers of 100 H. P. each.

Located close to the furnace are 60-60-cord beehive charcoal kilns. These make the charcoal used in the blast furnace and likewise furnish the volatile gases from which the chemicals such as wood alcohol and calcium acetate are obtained.

MANISTIQUE FURNACE.

The Manistique furnace, located as it is at Manistique, Michigan, has excellent railroad facilities by being on the lines of the Chicago, Milwaukee, and St. Paul, Sault Ste. Marie, and Ann Arbor Railroads. This stack was originally built by the Perry Chemical Company about 1890 and was acquired in 1910 by the present Lake Superior Iron and Chemical Company.

It has been out of blast since June, 1910, but it will probably go in blast again about June, 1912. Extensive changes have been made in the plant, and by the time it is ready to go in blast it will, without doubt, be one of the best equipped charcoal pig iron plants in the country.

The furnace is 59’ 6” high with a 12' 6" bosh diameter. The diameter of the throat is 7' 6" and of the hearth is 7', with a hearth depth of 5' 4”. Its rated daily capacity is from 110 to 120 tons of pig iron. The furnace is hand filled. The blast is heated by Durham hot blast pipe stoves which heat the air up to approximately 960° F.

Its blowing engine is of the Nordberg cross compound horizontal type with a rated capacity of 10,000 cubic feet per minute. There is also a Weimer vertical engine which has a capacity of 8,000 cubic feet per minute. The furnace proper will use about 7,600 cubic feet of air per minute under a pressure of 6½ pounds. Six Wicks vertical water tube boilers furnish a total of 1500 H. P. for the running of the blowing engines, pumps, and the other mechanical appliances around the furnace. They are equipped so as to use the waste gases from the blast furnace.

As new installation there is being erected a charcoal kiln plant very similar in detail to that which is found at the Newberry furnace and which will be discussed at further length in the description pertaining to the Newberry furnace.

NEWBERRY FURNACE.

Located on the Duluth, South Shore and Atlantic Railroad, in the town of Newberry, is a charcoal blast furnace known as the Newberry furnace. In 1910 this was acquired by the Lake Superior Iron and Chemical Company. It has been erected for a considerable period and has been in operation off and on for many years. Extensive repairs and alterations have been made recently and in fact are still being made. It is the expectation that about February 1st it will be in such shape as to permit its being blown in.

The furnace is 60' high with a 12' bosh; the diameter of the throat is 7' 6" and of the hearth is 7' 6". The height of the hearth is 6'. It is hand filled and has a capacity of 80 tons of pig iron per 24 hours. There are four twyeres, each one of which has a diameter at the end of the blow pipe of 4". It is expected that about 87 bushels of charcoal or the equivalent of two cords of wood will make a ton of pig iron.

Attached to the furnace are two Durham iron pipe stoves, each one of which has 16 pipes. It is the intention to heat the blast to a temperature of 950° F., and use a pressure of 5½ pounds. The blast is furnished by one Nordberg cross compound horizontal engine having a capacity of 10,000 cubic feet. There is also a Weimer blowing engine of 8,000 cubic feet capacity that can be used as a spare. In the boiler house are found 8 horizontal tubular boilers giving a total of 1,200 H. P.

When completed this plant will be equipped so as to get to as great an extent as possible all of the values that are found in the wood. Timber is brought to the company's saw mill and there sawed and such pieces as are of proper grade are sold for building purposes. The refuse from the mill, consisting as it does of odd ends, sides, and slabs too small for sale as lumber, are taken to the company's charcoal ovens for conversion into charcoal, wood alcohol, and calcium acetate.

The old plant consisted of 54-100-cord brick charcoal kilns. In using these it takes about 30 days to fill, fire, and turn a beehive charcoal kiln. The entire process is known technically as "turning." These kilns will still be used but only to a limited extent. In fact they will only be used for the using up of the large wood. The new installation consists of 20 retort kilns which are capable of daily carbonizing 160 cords of wood. Such an installation makes this the largest charcoal retort kiln plant in the world. Besides the 20 retort burning kilns there are 40 retorts for cooling, 20 of which are for the hot coals and 20 for the cooler coals. In cold weather it will probably be necessary to operate but the first set of coolers. Each retort is 47' long, 78" wide and 96" high. The volatile gases as they come from the burning of the wood give a light distillate which is essentially wood alcohol and also a heavy distillate. This latter product by further distillation gives tar and a product which, when treated with lime, gives calcium acetate. For the purpose of carrying out the chemical action a modern byproduct recovery plant is now nearing completion.

PINE LAKE FURNACE.

Formerly owned by the Boyne City Iron and Chemical Company, this furnace which is located at Boyne City was acquired in 1910 by the Lake Superior Iron and Chemical Company. It is located on the Boyne City and Southeastern Railroad. It is the one furnace owned by the Lake Superior people, of all those located in Michigan, which is at present in operation.

The pig iron plant proper, which we are chiefly interested in, consists of a furnace, cast house and stock house. The stack is 62' 9" high with a bosh 12' in diameter. The diameter of the throat is 6' 6" and of the hearth is 7' 2". The depth of the hearth is 6' 8". The furnace has two 2-pass brick stoves, each one of which is 60' high and 12' in diameter. It has a vertical blowing engine of 8,000 cubic feet capacity of the Waddington, McConnell, and Stevenson type. There are also three Wicks boilers furnishing a total of 750 H. P.

The furnace, which was originally blown in on January 1st, 1904, was in almost continuous blast for a period of 6 years and 8 months from that time. It was blown out on September 1st, 1911, for relining, but was blown in again on December 5th, 1911. The rate of daily output of the plant is 80 tons, and 88 bushels of charcoal are used per ton of iron made. The furnace is tapped every six hours. The limestone used is that obtained from the Petoskey Crushed Stone Company. Old range ores make up the basis of the burden. A charge at this furnace consists of two buckets of ore (1,250 pounds), two buckets of charcoal (500 pounds) and 60 pounds of stone.

The charcoal used comes from that furnished by the Boyne City Chemical Company. At the plant of this latter company there are 14 retort kilns of 10 cords of wood capacity each. But for the stunted supply of charcoal at the furnace there is little doubt but what the furnace could raise its daily capacity to a much higher degree than that stated in a preceding paragraph.

<u>MITCHELL-DIGGINS IRON COMPANY.</u>

In 1904 the Mitchell-Diggins Iron Company was organized in Michigan with W. W. Mitchell, President; J. C. Ford of Fruitport, Vice President and Secretary; and Fred A. Diggins, Treasurer. The plant is located at Cadillac on the Grand Rapids and Indiana and Ann Arbor Railroads.

This plant, more than all others at present making charcoal pig iron, is strikingly similar to coke blast furnaces. This feature is probably accounted for because Julian Kennedy, a prominent coke blast furnace engineer, was the designer of this plant. Its erection at Cadillac is accounted for by the fact that there are two large saw mills at that point and two wood chemical plants known respectively as the Cadillac Chemical Company and Cummer-Diggins Company. These firms had no adequate outlet for the charcoal which they produced as a by-product to the wood alcohol and calcium acetate values, and in consequence they assured the builders of the furnace plant a reasonable supply of charcoal at a reasonable cost if the furnace would take off their hands the supply of charcoal which they are continually making.

The stack has a height of 65' and a bosh diameter of 11' 4". The diameter of the throat is 7' 6", the diameter of the hearth is 7' 8" and the depth of the hearth is 6'. There are five twyeres, each one of which has a blowpipe diameter at the nozzle of 4". The blast pressure is about 6½ pounds. The capacity of the furnace is from 90 to 100 tons of pig iron per day.

The stoves, which are three in number, are 60' high and 16' in diameter and are of the Kennedy 2-pass type. They are exposed to the air and are the only charcoal stoves in Michigan which are constructed without shelter. The stoves are changed every two hours and the blast is heated up to from 1,100° to 1,250° F. There are three boilers, each one of 250 H. P. They are of the K. Hall horizontal type, and are equipped for using the waste gases from the blast furnace and likewise for burning coal. The blast is furnished by one Tod vertical blowing engine, with a rated capacity of 10,000 cubic feet per minute.

THE PIONEER IRON COMPANY.

This is one of the oldest pig iron producing companies in Michigan for it was on April 2nd, 1857, that the company was organized with a capital stock of $125,000. It is a. subsidiary to the Cleveland-Cliffs Iron Company. The officers at the present writing consist of G. A. Garretson, President; Wm. G. Mather, Vice President; E. V. Hale, Secretary; F. A. Morse, Treasurer; B. C. Mann, Auditor; and Austin Farrell, General Manager. The Board of Directors is made up of Wm. G. Mather, E. V. Hale, G. A. Garretson, J. H. Hoyt, Samuel Mathers and J. H, McBride.

This company controls three furnaces, two near Marquette and one at Gladstone, Michigan. Two of the furnaces are active; the one at Gladstone and one at Marquette. Detailed information in regard to these furnaces is found below.

CARP RIVER FURNACE.

In 1905 the Pioneer Iron Company purchased from Schaffer and Gray a blast furnace, located at Carp River, that is known as the Carp River Furnace. It was operated continuously throughout the years 1905, 1906 and 1907, making a brand of iron that is known as "Excelsior." It has not been operated since, however, because of the low price that charcoal pig iron has been bringing the past few years. In fact, it is quite probable that the furnace will never see further operation again as it is not equipped with many of the modern appliances and thus is in a condition preventing it from making pig iron at an economical figure. In fact the price of the iron would have to undergo a marked rise before its blowing in would be warranted.

The furnace itself is 58' high and it has a bosh 10' in diameter. It is filled by hand and is capable of producing about fifty tons of pig iron per day.

The fuel used is charcoal obtained from the company's beehive charcoal kilns of which there are 43 in number.

NO. 1 FURNACE AT GLADSTONE,

This furnace was built in 1896 by the Pioneer Iron Company at Gladstone, Michigan, but a short distance from Lake Michigan and near the port of Escanaba.

The furnace itself is 60' high and has a bosh 12' in diameter. It has a rated daily capacity of approximately 110 tons of pig iron, the brand of which, is known as "Pioneer." The furnace is filled by hand and has a single bell with a Weymer seal. It uses 4 pounds air pressure, has five twyeres with a 5" diameter blowpipe nozzle. Connected with the furnace are three Roberts-Cowper stoves, each one approximately 70' high and 16' in diameter.

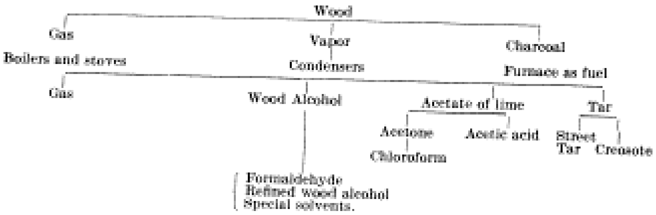
As a fuel the furnace uses charcoal obtained from 70 beehive charcoal kilns and 10 retort kilns. The wood put into the kilns is cut by the company's lumbering department. The smoke caused by the manufacture of the charcoal is used in the company's chemical plant for the production of various chemical products, chief of which are acetate of lime and wood alcohol.

NO. 2 FURNACE AT MARQUETTE.

This furnace was erected in 1903 by the Pioneer Iron Company, a subsidiary of the Cleveland Cliffs Iron Company. It is built very closely along the line of the company's furnace at Gladstone. The plant, however, is somewhat more modern and has several improvements, chief of which is Gayley's dry blast.

The furnace itself is 70' high and has a 13' bosh. It averages. about 120 tons of pig iron per day, making a brand known as "Marquette." A blast of 6½ pounds pressure is carried which gives a volume of 7,000 cubic feet per minute. The air is supplied by a double cross compound Southwark engine. The furnace is skip filled and has a Roberts revolving top. Connected with the furnace are three Roberts-Cowper stoves, each one 70' high and 16' in diameter. When but two of these stoves are used they are changed every two hours while with three stoves in use they are changed every 1½ hours. They heat the blast to a temperature ranging from 1,000° to 1,100° F.

For fuel charcoal is used, obtained from 86 kilns operated by the company and which are filled with wood cut by the lumbering department of the Cleveland-Cliffs Iron Company. Of the kilns there are 80 that are known as 80 cord kilns, each one of which is capable of producing about 3,500 bushels of charcoal per turn, and there are 6 kilns with a capacity of 90 cords capable, therefore, of producing a somewhat larger quantity of charcoal. The smoke coming from the kilns as the result of a charring of the wood is converted into various chemical by-products, chief of which is alcohol, formaldehyde, acetone and acetic acid. The flow sheet of a portion of this particular conversion which may be of interest is as follows:



In 1910 the plant was equipped with a Gayley dry blast, not so much for the purpose of reducing the charcoal consumption in the blast furnace as to enable the furnace operator to have uniform conditions in his furnace and thus assure the management of a uniform quality of pig iron. The expense attached to the installation seemed justified, for with pig iron selling at such a close margin it was necessary to take advantage of all methods which would tend toward the assurance of a uniform and standard quality of pig. At the present time about 92 bushels of charcoal are used per ton of pig iron produced.

The ores are some of those mined by the Cleveland Cliffs Iron Company at its various mines located in northern Michigan. They are of the high grade Old Range type and when dry contain 60% iron. .26 tons of slag are made per ton of iron produced.

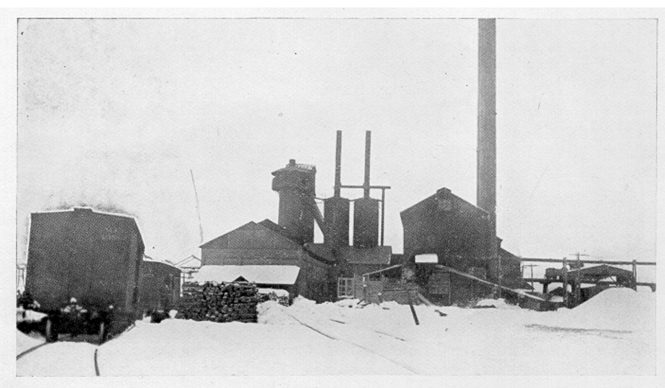


Plate XIII. A. East Jordan furnace.

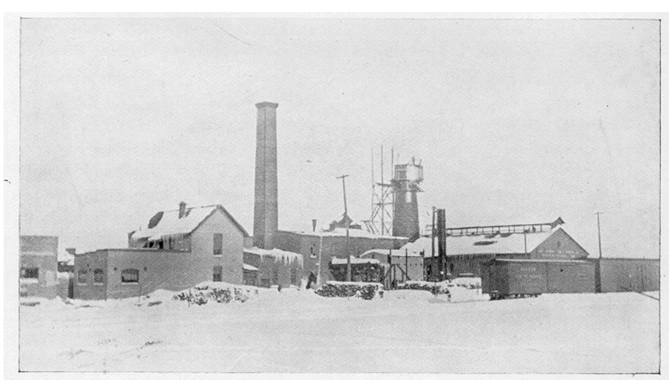


Plate XIII. B. Newberry furnace.

Plate XIV. A. Antrim iron furnace.

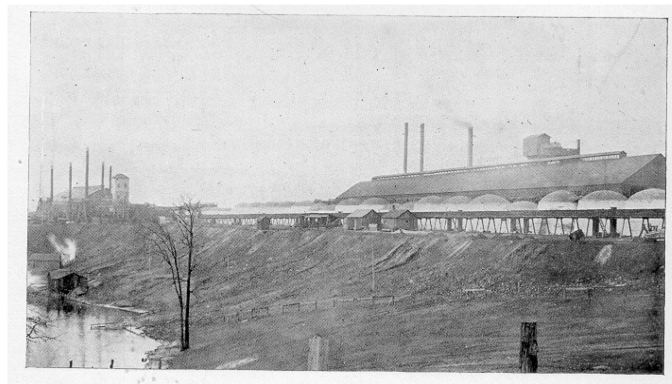


Plate XIV. B. Furnace and chemical works, Antrim, Michigan.

<u>SPRING LAKE IRON COMPANY.</u>

In 1879 the Spring Lake Iron Company was organized in Michigan with a capital stock of $30,000. A furnace was erected at Fruitport, Michigan. At this point direct connections by water can be had with Chicago, Milwaukee, and other distributing centers. The officers of the company are J. C. Ford, President and Treasurer, and Frank F. Bowles, Secretary.

The stack proper is 50' high and 11' in diameter at the bosh. The blast is heated by iron pipe stoves. The capacity of the furnace is about 75 tons of pig iron per 24 hours.

At present the plant is not in operation. This is in large measure due to the present dull condition of the pig iron market. In addition the furnace needs extensive alterations before further production can be carried out. These alterations and repairs will be made as soon as an improvement in the pig iron market conditions warrant.

<u>STEVENSON CHARCOAL IRON COMPANY.</u>

The Stevenson Charcoal Iron Company was organized on June 9, 1911, with a capital stock of $150,000.00. The plant is at Wells, Michigan and for transportation purposes is extremely well located, as it is on the Chicago and Northwestern; Chicago, Milwaukee and St. Paul; and Sault Ste. Marie Railroads. The officers of the company are Charles EL Schaffer, President; Grant T.

Stevenson, Vice President; and J. E. VanEvera, Secretary and Treasurer.

The erection of the plant at that point was in order to utilize the vast quantities of charcoal that are being produced there daily by the Meshek Chemical Company. It is expected that the furnace, which is now in process of erection, will be completed so that it can go into blast about July 1, 1912. The stack proper is 60' high and has a bosh 10' in diameter. It will produce about 60 tons of pig iron per 24 hours. Connected to the furnace are two fire brick stoves. There is also at the plant the usual apparatus consisting of such things as a blowing engine, pumps, boilers, etc.

COKE FURNACES.

Of the coke blast furnaces in Michigan there are three in number, and all, strange as it may seem, are located within the bounds of Detroit. One controlled by the Detroit Furnace Company has rather a small tonnage and resembles to a great extent a typical charcoal furnace in that it uses pipe stoves, is hand filled, and is of small capacity.

The two furnaces of the Detroit Iron and Steel Company are located on Zug Island, are in every way modern, and as far as operative costs are concerned should make pig iron at nearly as low figures as any pig iron plant in the country.

It is very probable that there will be no further coke furnaces erected within the bounds of the State for a number of years; largely because there is no great iron consuming center other than Detroit, and it is very probable that for many years to come there will be no one portion in Michigan which will rise to such an industrial condition as to be a large and important pig iron consuming center.

DETROIT FURNACE COMPANY.

The Detroit Furnace Company was organized on April 1st, 1906 with $150,000.00 capital stock. Its officers are J. O. Clutts, President; J. K. Pollock, Vice President; and C. F. Fraser, Secretary and Treasurer. The furnace plant itself has been built and in operation off and on for over 40 years. It was formerly controlled by the Wayne Iron Company, and up to the time of its purchase by the Detroit Furnace Company charcoal was the fuel used. The present management have, however, run it with coke, and this furnace, together with the two of the Detroit Iron and Steel Company, comprise the three furnaces which use coke in the production of pig iron in Michigan.

The furnace itself is 62' high and has a bosh diameter of 12' 6". The throat diameter is 7' 4" and the hearth diameter is 7' 6". The depth of the hearth is 7' 8". It has 7 twyeres, the blowpipe nozzle diameter of which is 3½". The blast pressure ranges from 5 to 7 pounds, and about 7,000 cubic feet of air is blown into the furnace per minute. The stated capacity of the furnace is about 75 tons of pig iron per day, and approximately 2,500 pounds of beehive coke is consumed in producing a ton of pig iron. About 1,650 tons of slag is made per ton of pig. The furnace is hand filled.

Connected to the furnace are three U-pipe stoves wherein the blast is heated from 600° to 850° F. The blast is supplied by 1-500 H. P. Weimer vertical blowing engine. The boiler installation consists of 5 horizontal Brownell boilers of 150 H. P. each.

DETROIT IRON AND STEEL COMPANY.

The erection of the plant of the Detroit Iron and Steel Company was the first important endeavor to locate within the bounds of Michigan a modern and up-to-date blast furnace plant in which coke was to be used as the metallurgical fuel. The company had its origin on April 24, 1902. There has been an issuance of $750,000 of preferred stock and $750,000 of common stock. The officers of the company are D. E. Hanna, president; F. B. Richards, Vice President; E. L. Ireland, Vice President; C. W. Baird, Secretary and Treasurer; Max McMurray, General Manager; and P. J. Moran, Superintendent.

The plant is located on Zug Island and lies between the River Rouge and the Detroit River. Such a location enables ore to be unloaded directly at the furnace. It has direct connections with the Michigan Central; Detroit, Toledo and Ironton; Detroit and Toledo South Shore; Wabash; Pere Marquette; and Canadian Pacific Railroads. Connections to these last three are via the Delray Connecting Railroad.

There are two stacks at the plant, one known as "A" furnace and the other known as "B" furnace. "A" furnace was built and put in blast about 1902, while "B" furnace was not erected and put in blast until July, 1910.

"A" furnace is 78' high, 18' 8" at the bosh, 12' 6" at the throat and 13' at the hearth. The depth of the hearth is 6'. It has 10 twyeres, the diameter of the blowpipe nozzle of which is 5". This furnace produces a tonnage of approximately 300 tons of pig iron per day and in doing so consumes from 2,200—2,400 pounds of byproduct coke per ton of iron. From 27,000 to 30,000 cubic feet of air is blown into the furnace per minute under a pressure of approximately 13 pounds. The blast is heated to a temperature of about 1,000° F. To do this there are 4 Garrett-Cromwell 2-pass brick stoves, each one of which is 83' high and 20' in diameter. The furnace was in continuous operation from the time of its erection until June, 1911, when it was taken off for repairs. At that time it had a ⅝" shell with a 42" brick lining. Since that time the stack has been entirely rebuilt and it has now a ¾" shell with a 12" lining. The stack is water cooled above the mantle, however. In addition to the water spray, 6 rows of bosh plates are in use.

"B" furnace, which was put into blast for the first time in July, 1910, has a ¾" shell with a 48" brick lining. The stack proper is 80' high. The diameter of the bosh is 18' 6", the diameter of the throat is 12' 6", the diameter of the hearth is 12' 6", and the depth of the hearth is 7'. The furnace makes approximately 325 tons of pig iron per 24 hours and in doing so consumes from 2,000 to 2,200 pounds of beehive coke per ton of pig. 32,000 cubic feet of air is blown into the furnace per minute at a pressure of about 13 pounds and at a heat varying from 1,100° to 1,200° F. There are 12 twyeres 5" in diameter at the nozzle of the blowpipe. The furnace is equipped with four Nelson-McKee 2-pass brick stoves, each one of which is 85' high and 12' in diameter.

Both furnaces are skip filled, "B" with a steam hoist and "A" with an electric hoist. Attached to "A" furnace is 1 large dust catcher, while attached to "B" furnace is 1 large dust catcher and 1 Mullin gas washer.

The blast is furnished by 5 blowing engines. On "B" there are two Allis blowing engines, each one 84" x 60". They are both of the long cross head disconnected compound type. On "A" there are two high pressure and one low pressure engine of the long cross head type. These last were made by the Tod Blowing Engine Company. Altogether there are 13 boilers at the plant; 8 are on "A" and 5 are on "B," giving a total of 2,000 H. P. The 8 "A" boilers are of the Babcock and Wilcox type, and the 5 "B" boilers are of the Wicks vertical type. Electric power is furnished by 1 Bullock 300 K. W. generator and 3-Elell-Parker generators of 200 K, W. capacity each.

The casting of the pig iron is done both in sand and in a Uehling single strand pig casting machine. The length of the strand, c to c, is 140'. In the cast house there is one Brown pig breaker.

For the handling of the raw materials and especially for the unloading of the ore from the boats there have been installed two Wellman-Seaver unloaders, each one of which has a capacity of 200 tons per day. There is also one Brown hoist unloader, with a daily capacity of 300 tons. These unloaders remove the ore from the boats, transfer it to stock bins and do other miscellaneous work.

The ores used at the furnace are of the Old Range and Mesaba grades, with an average iron content of about 51½%. "A" furnace uses by-product coke obtained from the Solvay Process Company's plant which is located just across the river, and "B" furnace uses Connellsville beehive coke.

THE J. T. JONES' STEP PROCESS FOR THE METALLIZATION OF LOW GRADE IRON ORES.

BY ALBERT E. WHITE.[1]

At the present writing there is probably no more interesting experiment being carried on, than that which Mr. J. T. Jones is conducting at Republic, Michigan. The experiment proper consists in the endeavor to convert into a commercial product the vast quantities of low grade iron ores which are found on the Marquette, Menominee, Gogebic, Vermilion, and Mesaba Ranges; but especially those found on the Menominee and Marquette Ranges. Mr. Jones has been working on this experiment since September, 1908. He has spent vast sums of money in carrying out his ideas and in making such changes as became necessary from time to time and there is little doubt but what in a very few months the results of his work will be definitely known, and one can then be certain as to whether or not the metallization of low grade iron ores will prove to be a commercial success.

Before proceeding further it should be made clear that it will probably become true that the Jones process will not be applicable to all types of low grade iron ores found on the iron ranges, but only to those possessing certain definite characteristics. In spite of this narrowing of the proposition, there is little question but what his process is applicable to extremely large quantities of iron ore, and for that reason it is the writer's belief that the vast sums of money which have already been spent are altogether warrantable. This narrowing of the process is but following the common law of all ore dressing operations, for in all work of this nature there is no one process or no one portion of a process which is applicable to all grades and types of ore.

Not since the early days when steel was made in this country in a Bessemer converter for the first time, at Wyandotte, Michigan, has an experiment been carried on containing such possibilities. There has never been an experiment carried on in the borders of this State which, if successful, will mean more to this State than the experiment which Mr. Jones is doing at Republic, and which had its origin and the beginning of its development at Iron Mountain. It is a process and a scheme which is worthy of the kindest criticism and which is well worth being financially backed for the possibilities of financial returns which it possesses.

The experiment in brief is to take low grade iron ore and by bringing it into contact with the volatile matters of coal or wood and likewise the fixed carbon which is found in the coal or wood it is expected that the oxygen will be driven out of the iron oxide of the ore leaving the iron in the ore in a metallic condition without in any way fluxing or melting the iron or gangue found in the ore—and then by a process of magnetic concentration the iron will be freed from its gangue and there will be obtained as a result a product by all means fit for blast furnace use and possibly of such a high grade as to be acceptable for open hearth use.

It is true that Mr. Jones has met with considerable criticism with regard to the possibility of success for his proposition. Most of this criticism has come from men who have vast sums of money invested in blast furnaces and other modern steel making appliances and who regard his process as Allen to their best interests rather than as a supplement to the present methods of iron and steel making now in vogue. Some have even gone so far as to condemn his proposition after but a very hasty and superficial glance at its possibilities and little if any weight should be given to such condemnation.

On the other hand there are many men who are warm supporters of Mr. Jones' idea. They realize the great hesitancy with which new schemes are first received. They further realize that at the start there are many factors which have to be met before any new proposition is worked out to a financial operating success.

Of course the crucial crux to the entire process lies in the amount of fuel which it will be necessary to consume in metallizing one ton of product. In an operation which Mr. Jones carried out last winter at Iron Mountain similar to the present one in principle although with a different type of roaster, 85 pounds of fuel was consumed per 100 pounds of product metallized. The inventor was taken sick and for a short period the writer handled the experiment and by judicial and careful work he was able to bring the fuel consumption down to 52 pounds of fuel per 100 pounds of product metallized. The writer, however, is of the firm belief that it will require but 40 pounds of fuel per hundred pounds of ore to bring about satisfactory metallization. In this figure he is assuming the use of fixed carbon alone. Theoretically it requires but about 26% of soft coal to do the work necessary in metallizing, and with an allowance of 40% there is therefore 15% excess. Of course there is no question but what the volatile matters in coal will metallize ore providing you keep the ore in contact with the volatile gases for a sufficiently long period. Such a thing as this is extremely difficult to do on a commercial scale for the volatile gases always have a tendency to escape and at the present time there is no mechanical appliance known that is capable of keeping the gases and a product such as low grade iron ore in contact for a period sufficiently long to allow of the complete metallization of the ore. It is because of the difficulty of metallizing the hydrocarbons that the writer has based his calculations on the fixed carbon found in coal.

There is a further possibility of making use of the large quantities of waste wood that are found in the vicinities of the low grade ore deposits for the metallurgical fuel to be used in the reduction. Such a possibility as this is worth considering on a small scale. It cannot assume large proportions, however, because of the fact that the supply of wood in the State of Michigan is rapidly decreasing and it will be but a question of time before the entire supply is practically consumed. For that reason it is only just that the process when looked at from the larger aspect should seek its fuel from coal.

Mr. J. T. Jones was led to the idea of conceiving the process for the utilization of the low grade iron ores because of the immense tonnages which are found in the Lake Superior region and because of the immense possibilities which a successful method for the treatment of the ores possesses. Before arriving at a scheme of metallizing he threw aside practically all other methods capable of containing possibilities for the recovery of the values found in the low grade ores. It seems to the writer that for the most part he was quite justified in taking the attitude which he did, for he was chiefly interested in the ores which were found in the Menominee and Marquette districts. These ores are quite hard and recent experiment has shown that they are not treatable in accordance with the modern methods of wet gravity ore dressing or milling.

The inventor at first felt, that with the proper tools he could reduce the iron found in the low grade ores to a metallic sponge, keeping the temperature throughout this portion in the operation at a point below the melting point of both the iron and of the slag forming constituents. When in a metallized condition the product was then to be heated to a temperature sufficiently high to flux the gangue—gangue which for the most part was silica and which was to be fluxed with iron oxide—but at a temperature not hot enough to melt the iron. It was then to be the endeavor to squeeze out the liquid impurities from the pasty iron. After many trials, however, it was learned that there was no known means of getting a fire brick lining which would stand up under the fluxing action of the iron oxide present in the product. To carry out this idea Mr. Jones erected near his home at Iron Mountain a large kiln 120 feet long and 8 feet in internal diameter which was supplemented with such necessary accessories as crushers, crushing rolls, elevators, screens, etc. His idea at that time was to put the ore into the kiln at one end and have it come out at the discharge end in such a condition that the slag would be liquid and the metallized metal would be pasty, capable of immediate working into commercial muck bar. The difficulty with this scheme as stated above was the fact that the lining of the kiln would not withstand the fluxing action of the iron oxide. All types and kinds of fire brick were used, including such kinds as magnesite brick, chrome brick, silica brick, fire clay brick, etc., but to no avail.

His next idea was to keep the temperatures in the kiln down to such a point as would metallize the iron ore present, but which in no way would result in a melting of either the ore or the gangue. At almost the first attempt Mr. Jones succeeded in getting the type of product which he wished: a product wherein all the iron oxide present in the low grade ore was reduced to metallic iron. His difficulty here was the fact that there was too high a consumption of fuel and the formation of a ring in the tube caused continuous operation to be an impossibility.

In order to overcome the first difficulty Mr. Jones conceived the idea of allowing the volatile hydrocarbon gases in the bituminous coal to do the work. Such action, he felt, would result in a reduction of the iron oxide to a spongy metallic iron. It is from this step that the process called "metallizing" has derived its name. He had been able to carry out this idea in a crucible test, for without any difficulty whatever he had converted the iron in an iron ore to a metallic sponge and the bituminous coal from which he had derived the necessary hydrocarbons was converted into coke. His great claim for the commercial success of the process lay in the fact that while he was converting the iron in iron ore to a metal he was, at the same time, producing a merchantable coke which, because of its value, would, in itself, more than pay for this particular step in the process.

So far Mr. Jones has had considerable difficulty in metallizing in his long tube by means of the volatile hydrocarbons. In fact one can state that as yet he has never succeeded in metallizing on a continuous commercial scale by means of the volatile hydrocarbons. Mr. Jones himself is aware of this difficulty and initially for the purpose of overcoming it, he inserted a charging door in his kiln two-thirds of the distance in from the feed end. At that point he inserted bituminous coal. His idea was to first allow the ore to become hot by means of contact with the escaping gases and through the combustion of a small quantity of fuel which he fed in with the ore, and after the ore had reached the necessary heat—which may be expressed as dull yellow because of the color of the ore—he added to it the bituminous coal which would furnish the hydrocarbons necessary to carry out the reduction of the iron in the iron ore to a metallic sponge. This step in the process was to be accompanied by the production of coke, for it was the endeavor to have the heat sufficiently great to free the coal of its volatile matter but not great enough to burn or consume the coke made after the expulsion of the volatile matter from the coal.

In carrying out this idea, two difficulties were encountered. In the first place the chemical and heat action at the point where the coal was fed into the tube was so great as to cause a superabundance of heat at this point. This caused melting of the gangue constituents of the ore and likewise a certain quantity of the iron in the iron ore was made metallic at this point. This caused it to become pasty. These conditions caused the materials to cling to the sides of the kiln in this vicinity and within 23 hours after this type of charging was resorted to, further use of the tube had to be abandoned until the ring was cleared away. The second difficulty was the trouble encountered in getting the coal which was charged through the side door underneath the ore burden. It was impossible to revolve the kiln faster than one revolution in 20 minutes. The kiln was fed with ore varying in sizes of from 2" pieces to as small as dust. The larger pieces went through the kiln at a much faster rate than the smaller pieces did. To secure complete metallization of the entire product, it was necessary to adjust the speed of the kiln to suit the larger pieces of ore. For that reason the slow speed had to be adopted. Because of the slow speed the ore as it passed down through the kiln slid rather than showered, and because of this sliding- action it was impossible to get the coal which was fed through the side door underneath the ore burden. For that reason the most of the possibilities that lay in metallizing through the use of the volatile hydrocarbons could not be utilized.

As a result, it was true that in practically all of the long runs which were made at Iron Mountain, the fixed carbon in the coal and not the volatile hydrocarbons was the agent which did the metallizing.

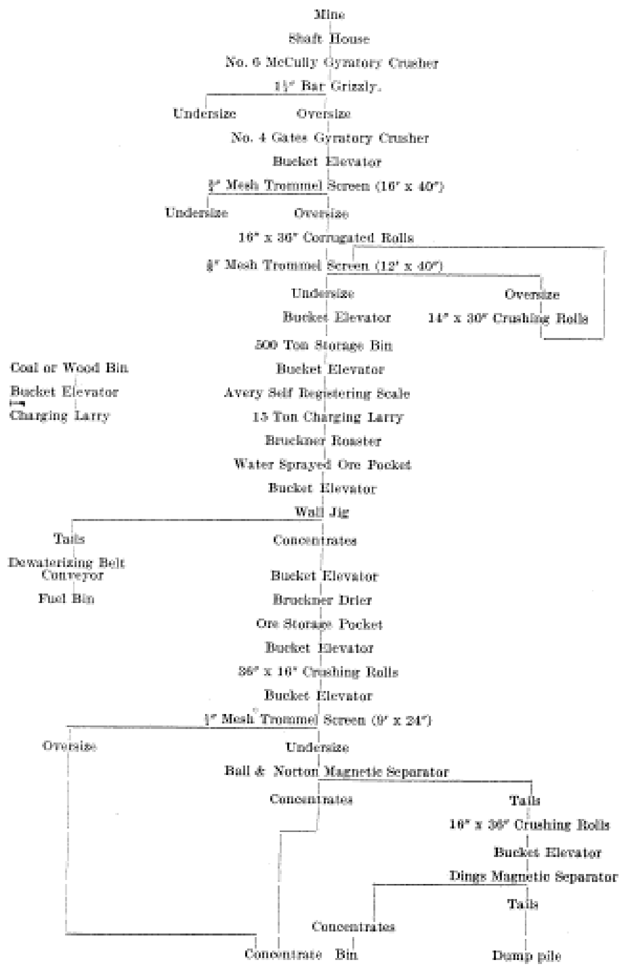
Mr. Jones appreciates this difficulty. In the early part of his experiments he endeavored to put lifters inside the tube. The lifters did not last, however, because the two kinds which he used were not adapted for the idea; the first one being a fire brick which was mechanically too weak to stand up and the other a concrete one which was not adaptable to withstanding heat.

In order to meet this issue more effectively Mr. Jones began, last spring, the erection of a metallizing plant at Republic, Michigan. He located the plant at the shaft head of the Kloman Mine for it is from this particular mine that the ore to be treated will be obtained. Mr. Jones has met with considerable criticism for utilizing this ore in his metallizing experiments, as it is claimed that it is the ore of ores on the Menominee Range most adaptable for the process laid forth. There is no question but what this ore is of a type which can be treated successfully in accordance with the proposed process, if any ore can be so treated. It appeals to the writer as though such criticisms are somewhat unjust because there is no question but what Mr. Jones has enough available ore in this one property to warrant the entire expense to which he has been placed if his proposition works out successfully and a proposition ought to be developed along lines most favorable for its advancement.

At the present writing it is the intention to mine the ore in the Kloman property according to the Glory Hole system made use of so commonly in the western part of our country, especially in the mining of our low grade copper ores. The ore will be hoisted to the surface and crushed in a No. 6 McCulley Gyratory Crusher. It will then be sized on a 1½ inch bar grizzly and the oversize will be again crushed on a No. 4 Gates Gyratory Crusher. The whole product will then pass through, rolls and screens until it is broken down to sizes ⅝ of an inch in diameter or smaller. The product will then be placed in Bruckner roasters, fifteen tons at a time, for the purpose of metallizing. These roasters are arranged in series of two. One is metallizing the ore while the other is having the ore which is present in it heated up by the passage through it of the waste gases from the first roaster. After the product in the initial roaster is metallized the ore is then dumped into a water-sprayed pocket. Fuel is then added to the second roaster, likewise ore is added to the first roaster. Metallizing then takes place in the second roaster with the passage of the waste gases through the first roaster for the purpose of heating up the ore therein. The metallized ore from the pocket is passed to a jig for the purpose of removing any good merchantable coke which may be present. The concentrates are then carried to a Bruckner drier and from there are crushed to a proper size and then magnetically separated; with a final concentrate of such a grade as can be used in a blast furnace as an ore or else as a product for open hearth use.

The detailed flow sheet of this process is as follows:

FLOW SHEET OF THE JONES' STEP PROCESS FOR METALLIZING LOW GRADE IRON ORES.



The Brunkner roasters themselves, around which centers the entire success or failure of the proposition, are of a type so commonly made use of in the ore dressing operations of non-ferrous metals. Each one is 18' 6" long and 8' 8" in internal diameter. They will require 12 H. P. to start and but 5 H. P. when in operation. It is expected that each one will hold fifteen tons of ore at a charge, and it is hoped that but four hours will be required for the metallizing operation; two of which will be consumed in heating up and two in the reduction or metallization. By having them placed in series of two and by having the waste gases from one pass into the other, it is expected that from the two roasters a charge of fifteen tons of ore will be available every two hours. The roasters themselves are equipped with oil burners for the purpose of giving the supplementary initial heat. Charges of coal will be put into the roasters at the proper time for the purpose of completing the reduction of the ore. The roasters have a 9-inch lining of fire brick and at definite portions throughout the inside shell of the roaster there are placed fire brick projections which will serve as lifters for the purpose, if possible, of getting the coal underneath the ore in order that the escape of the volatile gases may have an opportunity to come into as close contact with the ore as possible. The tube itself will revolve at varying speeds depending upon conditions. It has a variance of from one revolution in forty minutes to ten revolutions per minute.

The entire metallizing and concentrating plant is electrically driven throughout. For this reason it has the following motors installed:

1 75 H. P. A. C. induction motor. This for the No. 6 and No. 4 crushers, all the elevators in the crushing plant, and in fact everything up to the A very scale.
1 20 H. P. Variable speed reversible Western Electric motor. This for one tube and for ore elevator to Avery scale.
1 20 H. P. Variable speed reversible Western Electric motor. This for one tube and for driving the ore charging larry.
1 20 H. P. Variable speed reversible Western Electric motor. This for drier and for the coal-charging larry.
1 5 H. P. A. C. induction motor. This for coal hoist.
1 40 H. P. A. C. induction motor. This for separating plant.
1 6 H. P. D. C. generator. This to be driven by the 40 H. P. motor for the purpose of generating D. C. for the magnetic separators.
1 5 H. P. A. C. induction motor. This for a No. 2½ centrifugal pump.

To carry out the housing of this experiment it has been necessary to erect a set of completely new buildings. These are altogether of the reenforced concrete type. Three large buildings have been constructed, one of which is known as the Generator Building, another as the Boiler House and Machine Shop Building, and the third as the Mill. The first of these, or the Generator Building, is 40 feet long and 30 feet wide. It consists of but one story and is 11 feet high. In it is 1-200 H. P. Corliss Engine and 1-150 K. W. Western Electric A. C. Generator, furnishing 440 volts. This generator is equipped with an excitor, switch board, rheostat, and the other paraphernalia which go to make up an electric station.

The Boiler House and Machine Shop is all under one roof, in a building 125 feet long, 18 feet wide and 8 feet high. The Boiler House proper is 40 feet long and 18 feet wide; and the Machine Shop, containing as it does the air-compressors and hoists, is 60 feet long and 18 feet wide. The Boiler House contains 1-250 H. P. Continental water tube boiler. There is also 1-15 H. P. upright boiler and 1 exhaust water heater. In the Machine Shop section of the house is found one ten drill Ingersoll-Sargeant Compressor, one four drill compressor of the same type, one Webster-Camp & Lane five foot drum 2nd motion hoist, one 20 inch lathe, one drill press, and one shaper.

The Boiler and Generator Houses are placed at a distance of about 400 feet from the Mill. The Mill is directly at the head of the shaft. This arrangement will be noted from an examination of the accompanying photograph. The general arrangement of the layout in the Mill can also be noted from an examination of the flow sheet of the process found in this chapter.

At the present time there is a great difference of opinion as to just what the cost of making iron from metallized ore will be. If it is possible to get a product containing approximately 95% of iron, and from 4% to 5% of gangue with but about .05% sulphur there will be no question but what this product could be successfully used in an open-hearth furnace. It is true that there might be some objection to its use there on the claim of its fineness, but because of the general nature of the Kloman ore it will probably be true that such an objection will not hold.

Plate XV. Plant of Kloman Mining Company at Republic, Michigan.

The main trouble will probably be with its quality. It will probably be certain that it will be impossible to obtain a product containing more than 85% of iron, and such a product, because of the high percentage of gangue necessarily present, would find no ready sale for open-hearth use. There is another great objection, which as yet has not been emphasized, and that is the tendency which this material possesses to absorb sulphur from the surrounding coal with which it is in contact. It will very probably be true that a final product will be secured from the metallizing plant containing not less than from .1% to .2% sulphur. For this particular reason it will probably be true that the natural outlet for the use of this material will be in a blast furnace. For that reason the fears of so many people that the installation of the Jones process for the utilization of the low grade iron ores will completely revolutionize the present practice of making steel is nothing more nor less than a visionary bubble.

ESTIMATE OF COST OF METALLIZING AND SMELTING LOW GRADE KLOMAN IRON ORE.

Mining	2.66 tons at $0.30	$0.798
Crushing	2.66 tons at .08	.213
Screening	2.66 tons at .05	.130
Concentrating	2.66 tons at .08	.213
Conveying	2.66 tons at .10	.266
Jigging	2.66 tons at .05	.133
Fuel		3.180
Repairs	2.66 tons at .10	.266
Tailing disposal	1.66 tons at .08	.133
Freight	1.00 ton at 1.50	1.500
Total cost at Chicago		$6.832
Cost per unit at Chicago		.08

SMELTING.

Ore	1.18 tons at $6.83	$8.06
Stone	.50 tons at 1.00	.50
Coke	1000 lbs. at 4.50	2.25
Labor and repairs		1.25
Cost per ton of pig iron at Chicago		$12.06

ANALYSIS.

	Crude ore per cent.	Concentrates per cent.
Iron	40	85
Silica	35	12.5
Other gangue	7	2.5
Moisture	1	

In arriving at this estimate the natural ore is credited with containing but 1% of moisture and 42% of gangue of which, 35% is silica. As we lose 20% of the iron present in our process of magnetic concentration it becomes true that it will be necessary to use 2.66 tons of crude ore in order to get a concentrate containing 85% of iron.

It has been the endeavor to make the crushing, screening, concentrating, conveying, jigging, and repair costs full high and there is little doubt in the writer's mind but what the actual operating costs of certain of these items will be materially reduced when operating on a large scale.

The smelting center adopted has been Chicago. The cost of the metallized ore at this point will prove to be approximately $.08 a unit. It will roughly require ½ a ton of limestone to do the necessary fluxing. The amount of coke that would be required to smelt this product is at present a matter of mere guess work. Allowing .8 of a ton of coke for a ton of silica as our basis for the amount of coke required to flux out the silica and 300 pounds of coke for a ton of metal as our basis for melting the metallic iron present in the product it will be noted that but approximately 500 pounds of coke are required per ton of pig iron. 1,000 pounds have been allowed and the doubling of the requirement seems more than ample.

Adding up all of the various items it can be observed that it will cost approximately $12.00 to make a ton of pig iron out of many of Michigan's vast number of low grade iron ore deposits. It is believed that this figure allows ample allowance for any contingencies that may come up. It does not take into account the fact that there is a possibility of making a soluble coke as a byproduct. It does not take into account the fact that there is a possibility that a product of high enough grade for open hearth use may be made. It has put, colloquially speaking, the worst foot forward and the figures show that it is a proposition worth developing.

We will all watch with great interest the growth of the ideas which Mr. J. T. Jones has clung to so tenaciously the past few years and we sincerely trust that within the next six months he will be able to break down the present bars of skepticism, by having at hand actual proof concerning what can be done with regard to the metallization of certain types of Michigan's low grade iron ores.

[1]Instructor in Chemical Engineering University of Michigan.