Taconite Industry
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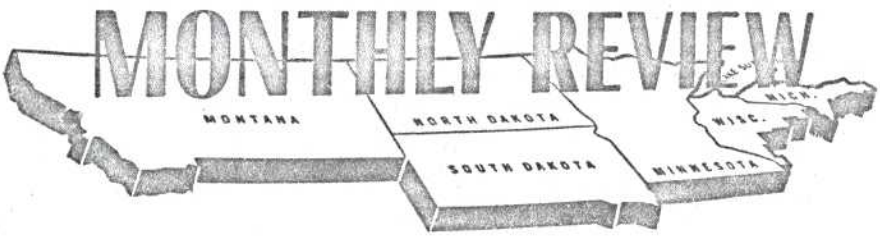
The taconites of Minnesota and jaspery, iron-bearing rocks of Upper Michigan are raw materials for a new industry that will invest several hundred million dollars to "manufacture" high grade iron ore. The nature of the raw material and the plant construction now in sight are surveyed briefly in this report.

FEDERAL RESERVE BANK OF MINNEAPOLIS

MONTHLY REVIEW



February ◆ SUPPLEMENT ◆ *1953*

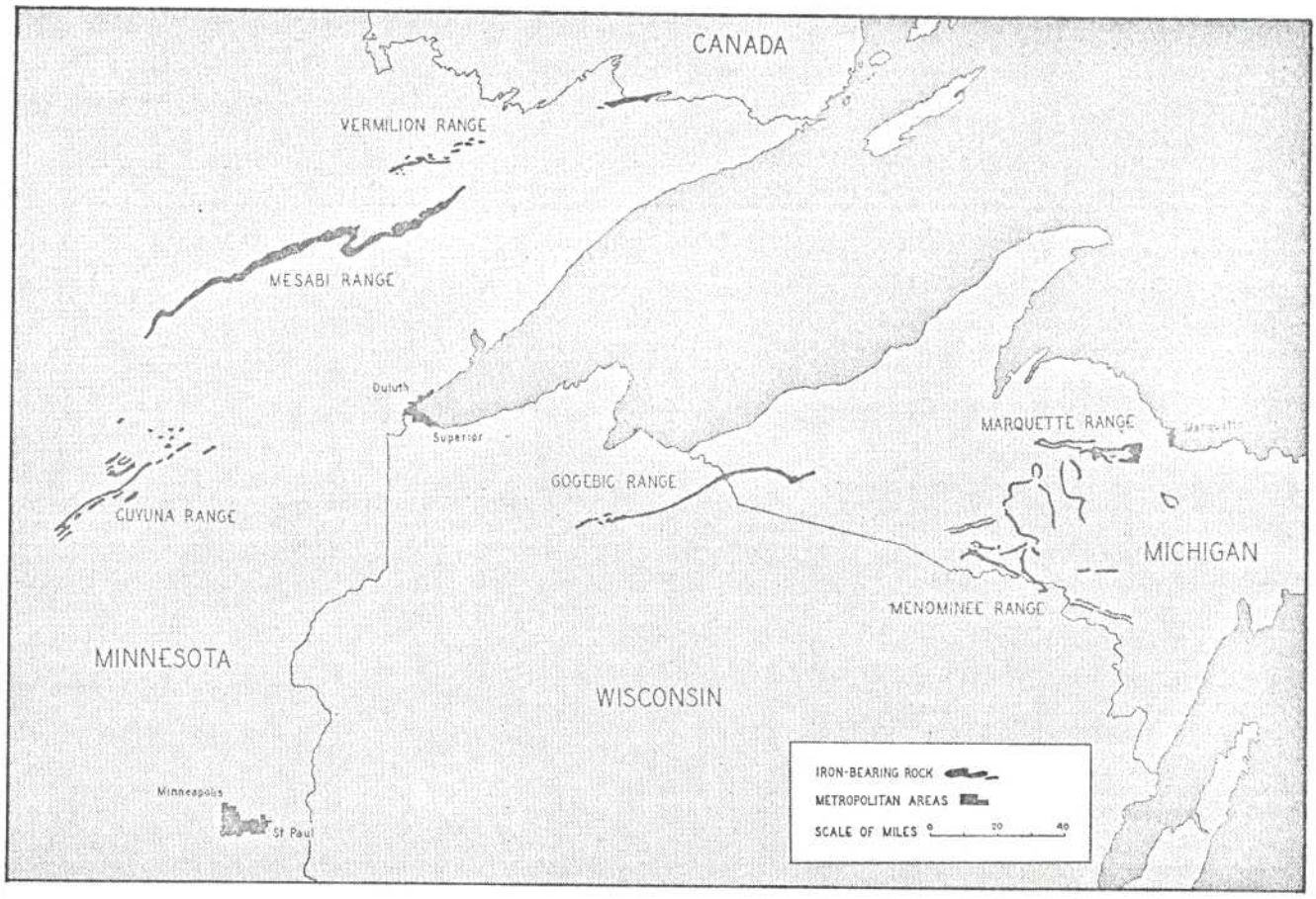
TACONITE: Source of Tomorrow's Steel

NOW UNDERWAY on the iron ranges of Lake Superior is one of the most important ventures in the history of iron mining and a major economic development for the district. Two large, heavily equipped industrial plants will soon begin the manufacture of high grade iron ore out of a hard, iron-bearing rock called "taconite." Preliminary plants are already in operation, and other projects are under consideration as part of the industry now developing around Lake Superior.

Heavy steel demand has depleted the richest iron ores from Lake Superior ranges (by far the country's most important) to the point where new sources have had to be found. The search has been underway for at least 10 years, and it now appears that "manufactured" iron ores will one day be our biggest and most reliable source of supply.

The taconite program is a costly but inevitable outgrowth of rising steel consumption and declining ore

CHART 1 — IRON RANGES OF THE LAKE SUPERIOR DISTRICT



FOUR-FIFTHS of all iron and steel used in this country lay originally as iron ore along the ranges depicted here. Scooped from giant open pits or blasted from flint-hard underground formations, rich ores from the Lake Superior district are lifeblood to the American steel industry. Gradual depletion of many of the better deposits has led to the birth of a new industry based on taconite and other iron-bearing rocks of these ranges.

supplies. More than 30 years ago an attempt was made to process taconite on a commercial scale, but it proved premature. Costs were too high relative to prices and the plant failed.

With the tightening ore supply outlook, however, taconite processing has come of age. Taconite, in spite of high costs, has become an important part of plant expansion programs of several steel companies.

This report considers some of the problems of processing taconite, and the projects planned by companies now involved in its development. The Mesabi range, where most present activity centers, is the subject of Part I of the report. Part II takes up other Lake Superior iron ranges (those of Upper Michigan and Wisconsin), while Part III reviews some of the economic implications of this development.

Part I—THE MESABI RANGE

The iron ranges mapped in Chart 1 outline the major deposits of iron-bearing rock. On the largest of these ranges, the Mesabi, such rock has been named taconite. Taconite at best is only about one-fourth iron, the remainder being a mixture of valueless minerals. Each of the other ranges is composed of rocks similar to taconite, but because of differences in their physical makeup their commercial significance varies.

As outlined in Chart 1, the Mesabi is a long, narrow ribbon of iron-bearing rock. On the surface it runs about 110 miles from west to east and varies from ½ to 3 miles in width. The cutaway view of the Mesabi (Chart 2) shows that the long strip is actually the sheared-off edge of a tilted, 700-foot thick series of rock layers that slope underground in the general direction of Lake Superior.

The grey, shaded zone in the diagram is the taconite series. Rock layers above and below the taconite do not contain iron.

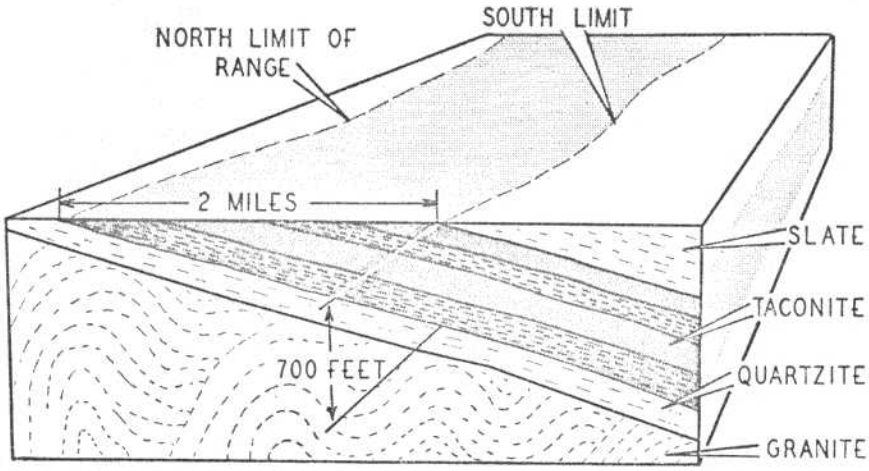
In only a few places are the protruding edges of these rock layers visible on the surface. Most land in the Lake Superior area is covered with drifts of sand, gravel and boulders—the remnants of glacial invasions. On the western part of the Mesabi the iron-bearing rock is buried by as much as 300 feet of debris, whereas outcroppings in the eastern section are fairly frequent. Despite this cover, drilling has accurately mapped the extent of the range.

Sea-Born Iron Range

The layers shown in Chart 2 were originally built up as sediments on an ancient sea floor. Vastly older than known oil-bearing rocks, these deposits were stream-carried into a sea devoid of all but the most elementary life. Scientists tell us that primitive bacterial forms inhabiting the sea literally "ate" iron compounds dissolved in sea water, and in this way helped settle iron materials to the bottom.

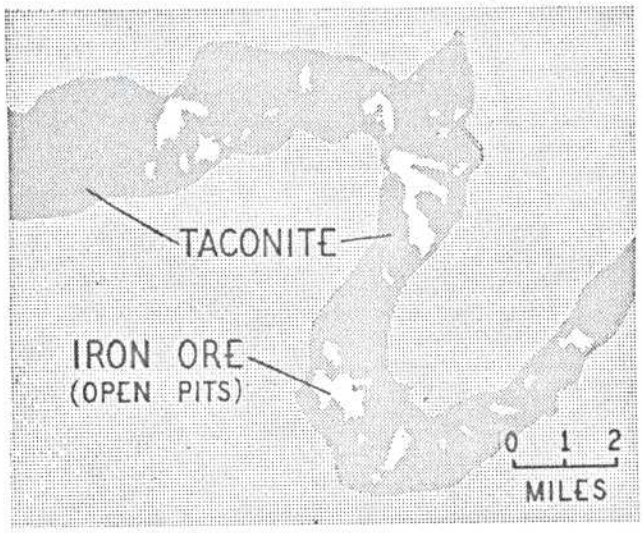
The sea floor at the time was a layer of fine sand (now the quartzite) on top of which collected a jelly-like assortment of iron, silica, and other minerals carried in by streams. Intermittently, layer upon layer of sea floor was built up, sometimes rich in iron, sometimes lean, until several hundred feet of the material had gathered.

CHART 2—CROSS SECTION OF THE MESABI RANGE



SURFACE LIMITS of the Mesabi are defined by the area where the taconite layers (the wedge-shaped grey zone) reach ground level. Scattered along this surface edge are the iron ore deposits presently mined. The gentle slope of the taconite layers (actually about 8°) is exaggerated in this cross-section view of the Mesabi range looking eastward.

CHART 3—OPEN PITS NEAR CENTER OF MESABI



Later on the streams that fed the sea brought no more iron; the accumulations were overlain with clay, and from this the slate that lies above the taconite layers was formed.

Since that early beginning, the whole series of layers has been tilted, raised to dry land, and compacted by heat and pressure into one of the hardest rocks on the continent.

Today's Ore Was Once Taconite

Ground waters seeped through cracks and fissures in the aging formation and turned a small fraction of it into high grade iron ore by washing away the silica and leaving iron oxide behind. The tremendous tonnages of iron ore shipped from the Mesabi have come from these relatively localized spots of "weathering." In area they total less than 10,000 surface acres. A rough idea of the extent to which ground waters weathered the taconite and converted it to iron ore can be gained from the close up map of the center of the Mesabi in Chart 3.

The open pits at this late stage of the range's development pretty well show the surface extent of high grade ore. The rest of the formation—perhaps 90 percent or more of the accessible material that makes up the range—is taconite.

Taconite—A Close Look

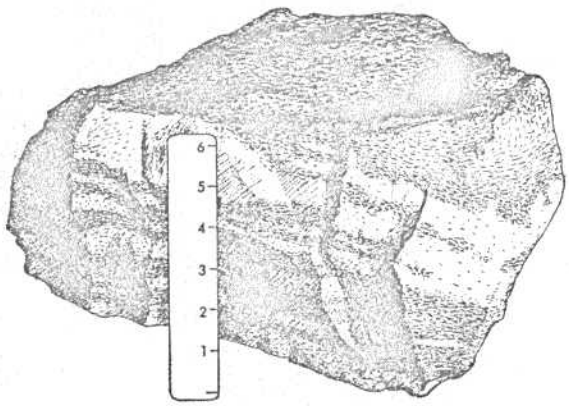
To the eye taconite is a salt-and-peppery looking gray-green rock closely veined with irregular dark bands that are richer in iron than the lighter parts. A chunk of it looks something like the sketch in Chart 4 below.

A surprisingly small portion of this rock is usable—most of it is waste. In a piece of taconite representative of the east-central Mesabi, mineralogists can identify four main kinds of minerals as follows:

Iron oxides	35%
Iron silicates	20%
Iron carbonates	5%
Chert	40%

They are combined in the rock in an endless number of ways so that no two pieces have exactly the same composition. Of the four, the iron oxides are the only ones useful in the manufacture of iron and steel. Since they make up only about a third of the rock, it takes at least three tons of crude taconite to yield a single ton of usable product.

CHART 4—REPRESENTATIVE PIECE OF TACONITE

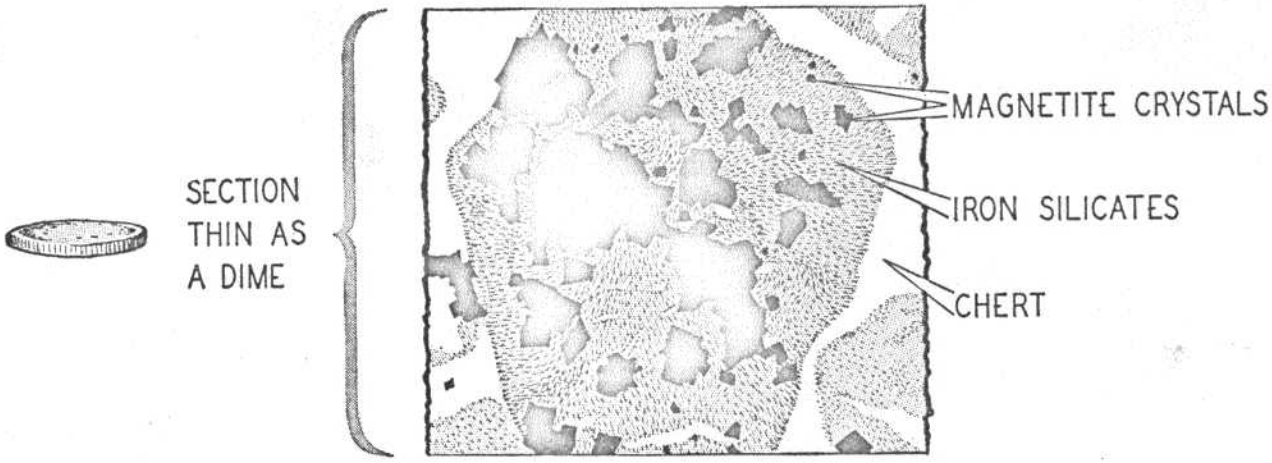


EDITOR'S NOTE: The author of this article, *Clarence W. Nelson,* assistant economist, has conferred with various authorities who have been helpful in the preparation of this manuscript. Acknowledgments are made on last page.

The bank as publisher wishes to absolve all persons who have aided the author from all responsibility for any errors of fact or interpretation in this manuscript.

The bank's Monthly Review is a periodic summary of trends in district banking, business and agriculture. More detailed analyses of important developments, such as the present article, are presented in the form of a special supplement.

CHART 5—MAGNIFIED VIEW OF MINERAL GRAINS IN TACONITE



BLACK PATCHES in this sketch are tiny grains of magnetite tightly imbedded in waste rock. These microscopic crystals of iron oxide can be liberated only after grinding has reduced the rock to a fine powder. Magnetite makes up only about a third of the rock, even in the best grades of taconite found on the Mesabi.

Iron oxides are found in two main forms, and have one important difference. Magnetite (a fine-grained, black mineral) can be readily picked up with a magnet, while hematite (red rust is an example) is practically nonmagnetic. In the commercially usable taconite of the Mesabi—like the piece illustrated—nine-tenths of the iron oxide is in the form of magnetite.

About two-fifths of the rock is made up of chert—a fine-grained colorless quartz. Chemically, chert is composed of silica and is strictly a waste product.

The remaining minerals consist of iron silicates and iron carbonates occurring in colored needles, grains and intricate patches. Both types of minerals contain iron, but it is difficult to salvage iron carbonates in processing and impossible to salvage iron silicates. They are waste materials as far as present methods are concerned.

One of the biggest challenges to the new industry arises from the extreme fineness of the mineral grains that compose the rock—grains so small they can be seen only under a microscope. An enlarged view of a thin sliver of taconite is illustrated in Chart 5.

The black areas are crystals of magnetite. An average grain is less than 4 thousandths of an inch in size. The largest groupings, actually clusters of these minute grains, rarely run more than 20 thousandths of an inch across—no larger than the period at the end of this sentence.

The remaining area of white and grey represents the so-called "gangue" minerals (largely chert and iron silicates). These waste materials effectively bind magnetite grains into one of the toughest rocks known.

Processing Mesabi Taconite

Processing taconite requires grinding the rock fine enough to free the microscopic grains of magnetite, then sorting the tiny particles from the rest of the material—tons at a time.

The crude rock has so little magnetite that it averages less than 25 percent recoverable iron. Pure magnetite, on the other hand, would make a wonderful iron ore—over 70 percent iron. Since no sorting is perfect, the best commercial products run 60 percent to 65 percent iron. (Present Lake Superior natural ores average about 51 percent iron.)

Naturally, ores with higher iron content bring more money on the market because they will produce more pig iron per ton and require less coke and limestone. Other factors that will help determine the price of "manufactured" iron ore are the impurities contained and the form of the product. Silica and phosphorus must be kept below established standards to obtain premium prices. Structure is also important. Great pains are taken to properly form the product into pellets or nodules that can be easily reduced in the smelting process. (Coarse-structured ore is much preferred over loose, powdery ore.)

After a brief look at the steps required to produce an acceptable blast furnace ore from taconite, it can be readily appreciated why the investment involved in processing equipment is so large, and why the operation is referred to as "manufacturing." Chart 6 shows in simplified form how high grade iron ore is manufactured from taconite. The steps fall into three main groups, according to their function.

Freeing Magnetite Grains

The function of the first four steps in the diagram (crushing, grinding, sorting and more grinding) is to fracture crude taconite rocks into finer and finer pieces until the minute grains of magnetite are substantially freed from the chert and silicates in which they were originally embedded.

Magnetite grains are of the order of 2 thousandths of an inch. Blocks of taconite as they come from the quarry may be up to 4 or 5 feet across. Therefore, this particular arrangement of machines must be able to batter and pummel the raw stone until the fragments are no larger than 3 to 5 thousandths of an inch as they leave the final grinding step.

In practice there are many possible arrangements and elaborations of the set-up shown in Chart 6. Ordinarily three or four crushers are used, so that a boulder can be reduced to pebbles in progressive stages. A number of rod mills may then be fed simultaneously from the output of the last crusher.

The rod mill consists of a rotating drum partly filled with tumbling steel rods. Taconite pebbles and water, fed in at one end, are pounded into a soupy, black mud that flows out at the other.

Ball mills are very similar to rod mills except that they are partly filled with steel balls and do a finer grinding job.

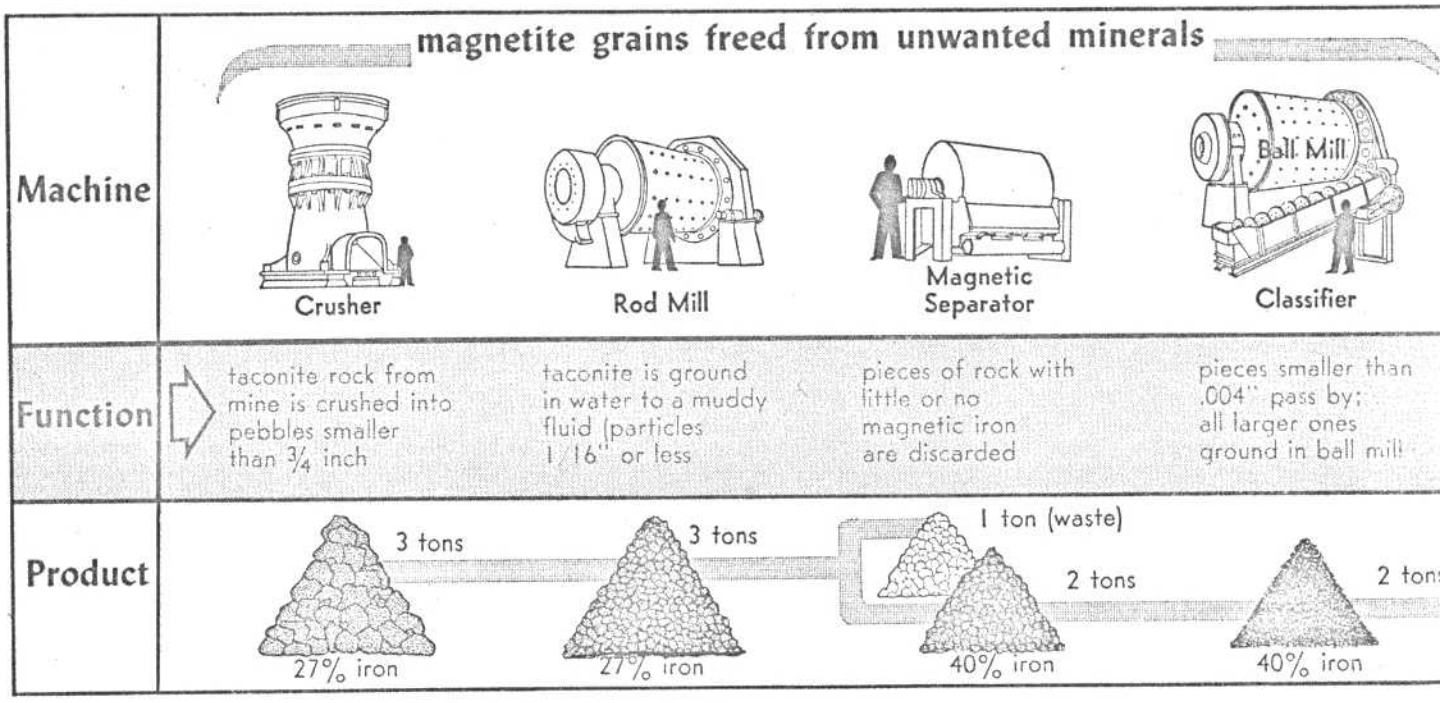
Sorting and separating equipment in this first group of steps helps to eliminate as much waste as possible early in the process and so reduce the amount of material that must be ground and handled in later steps.

Separating Magnetite From Chert

The next step, separation, is the heart of the process. In practice it is a good deal more complicated than the single machine shown in the diagram, but the principle is the same. As the finely ground mud moves through the separator, electromagnets draw the tiny particles of magnetite to the surface of a rotating drum while nonmagnetic particles drop away and are discharged as waste.

The concentrate that leaves this step has reached its final purity. The product is mostly magnetite, but frag-

CHART 6—MASSIVE EQUIPMENT, SKILLED TECHNICIANS ARE



ments of chert and silicates always manage to ride along. Iron content is now very high—in the neighborhood of 64 percent, while the remaining silica amounts to about 8 percent.

As indicated before, some of the iron present in the rock cannot be picked up with a magnet (that in the form of hematite or iron silicates). So the waste that slips away carries most of these other iron minerals along with it, and is actually about 8 percent iron.

Forming Magnetite Into Pellets

The last group of steps in taconite processing combines the extremely fine particles that leave the separators into "lumps." This is necessary in order to prepare the product for blast furnace use. At least three different methods are under commercial consideration. The most popular is illustrated in the diagram.

In this process, water is sucked by vacuum from the soupy, black concentrate flowing over the filter drum, converting it into a thick mud that will cake easily.

The mud then enters a slightly inclined rotating drum. By the time it has tumbled and rolled to the far end, it has formed into an endless procession of round pellets.

The pellets (about an inch in diameter) are highly cohesive, but heat treatment is necessary to make them hard and solid—ready for the rough handling they receive between the plant and the blast furnace.

Large Investment Planned For The Mesabi

Well over $300 million in investments is planned for the two large commercial plants and one experimental plant scheduled for operation on the Mesabi within the next five years. Each of these plants will use huge machines similar to those just described to process magnetic taconite.

Chart 7 is a map of plant proposals for the Mesabi. They are located on the eastern portion of the range where the most extensive taconite deposits suitable for present commercial processes are to be found.

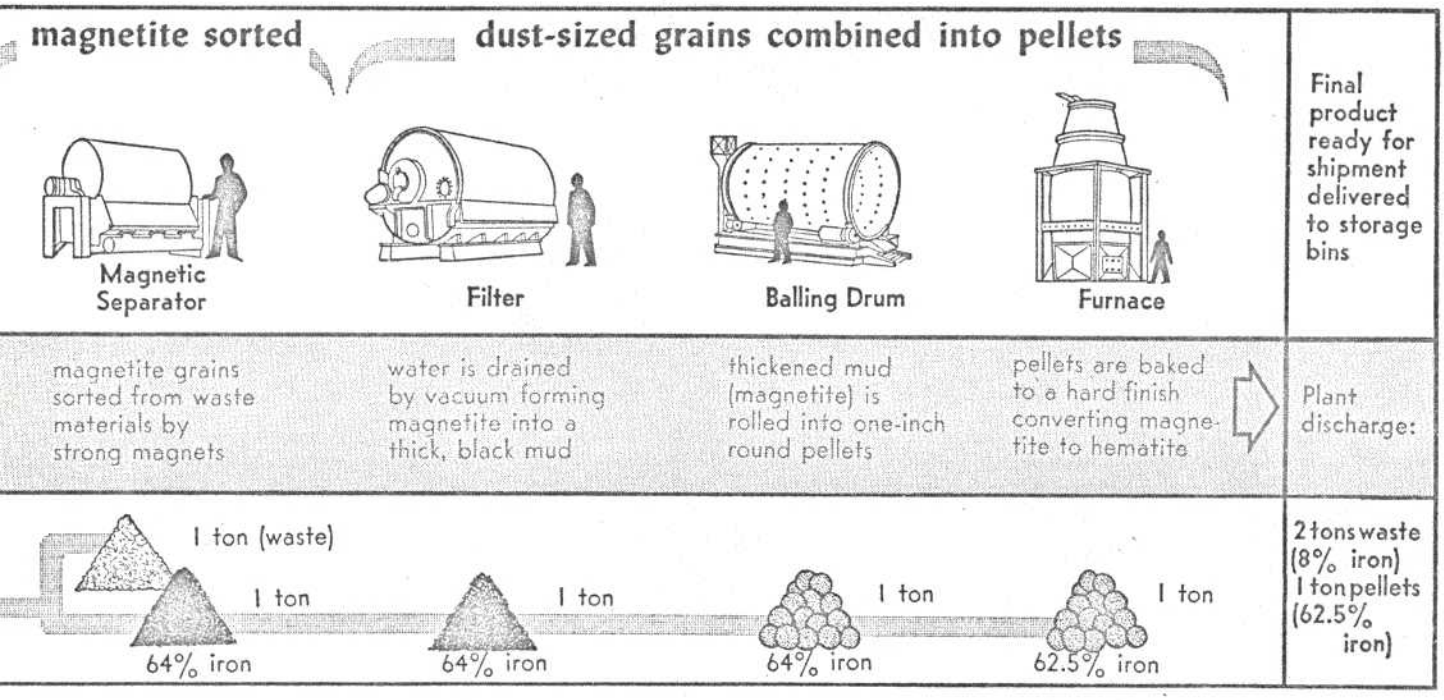
Reserve Mining Company

One concern, Reserve Mining company,* has a small plant now operating at Babbitt, Minnesota. The small unit serves to train an organization for a much larger plant to follow, and to turn out pellets that will give blast furnace operators some experience with the new product.

Their present plant, housed in the same buildings where one of the first attempts at taconite concentration was begun 30 years ago, has a capacity output of 300,000 tons of high grade ore a year.

*Owned jointly by Republic and Armco Steel Corporations.

HIGH-COST REQUIREMENTS OF TACONITE PROCESSING



A large plant capable of producing 3,750,000 tons of concentrates per year is now under construction. Its facilities will be divided between two locations. The quarry and main crushing machinery are to be located on Reserve's 10,000-acre properties near Babbitt.

The largest part of the installation will be north of Beaver Bay on Lake Superior and will house the operations of grinding, magnetic separation, and pellet-forming. The work will be accomplished in two stages—two-thirds of it should be ready by 1955, and the remainder by 1957.

Other large auxiliary facilities required by the taconite project include a 47-mile railroad (to carry crushed taconite from Babbitt to the lakeside plant), an ore loading port north of Beaver Bay, and a power plant.

To meet housing needs of employees, two complete carefully-designed towns are now under construction. One will be located at each of the installations, and together they are expected to house a total of 9,500 people at the end of five years' time.

Reserve has plans for an eventual annual capacity of 10,000,000 tons.

Erie Mining Company

A few miles northwest of Aurora the Erie Mining company* has had a small scale taconite plant in operation since mid-1948. Rated capacity of the unit is close to 200,000 tons a year.

Based on this experience, Erie is laying plans to expand into large scale commercial production. The project anticipates a huge installation near the site of Erie's present plant at Aurora that will house all the machinery from first crushers to final pellet-forming drums. This will be even larger than Reserve Mining company's program. Certificates of Necessity have been filed covering a 10,500,000-ton project estimated to cost about $300 million.

According to present plans the initial unit will have an annual capacity of at least 5,000,000 tons, with the probability that when the program is started construction will continue until the 10,500,000 tons per year capacity is reached.

Like Reserve, the Erie company will also have its own railroad from the plant to Lake Superior. This one is to connect the Aurora plant with harbor facilities at Two Islands on Lake Superior. No construction has begun yet, but the preliminary work is almost completed.

*Owned by Bethlehem Steel Corporation, Youngstown Sheet & Tube Company, Interlake Iron Corporation, and Steel Company of Canada.

Oliver Iron Mining Division

Oliver Iron Mining Division of United States Steel Corporation will complete the second unit of a two-unit experimental project this year. Unlike the previous two companies, Oliver is not undertaking a large scale commercial plant. The facilities now being constructed are for the purpose of making an overall economic study as a basis for whatever future projects might be undertaken.

Even so, the plant's slated output of about 500,000 tons of concentrates per year exceeds the combined capacities of the two present small plants at Aurora and Babbitt.

The concentrating unit being built north of Mountain Iron will carry through the grinding and separating stages, while the agglomerating unit, located near Virginia some five miles to the south, will complete the processing.

This agglomerating unit (already completed) is equipped to form lumps from the concentrate by either of two processes—each different from the pelletizing process shown in Chart 6.

One method, called sintering, burns the magnetite powder (mixed with a little pulverized coke) on a moving grate. The ash formed is a porous clinker of partially fused iron oxide which is then broken into lumps of convenient size.

The other method, called nodulizing, feeds the damp magnetite "cake" into the high end of a long, rotating tube that is actually a brick-lined kiln. Hot flames are shot into the low end of the kiln, heating the magnetite so that it becomes sticky and forms balls as it works its way down to the discharge.

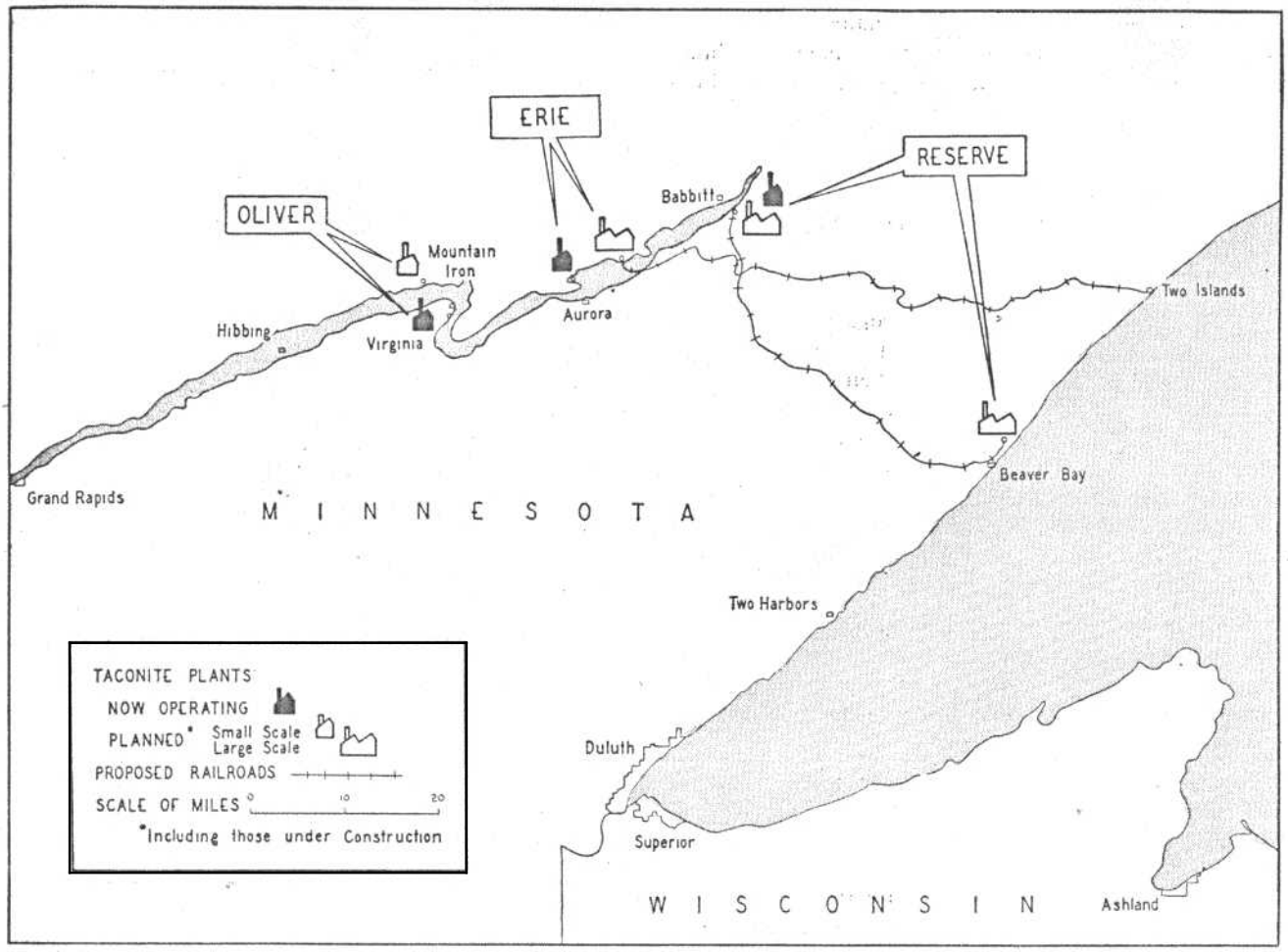
This phase of the project has gained a head start by practicing on a fine, rusty powder screened from hematite ores mined in the locality. Its capacity matches the concentrating unit's 500,000 tons a year.

The whole project is a very imposing experimental undertaking, requiring an investment in the neighborhood of $23 million.

In Summary

This preview of the industry that may become a part of the Mesabi range economy during the next five years covers only the first round of developments. Production from those facilities is expected to reach 6-7 million tons a year by 1957. In contrast, current yearly iron ore production from Mesabi range mines runs 60-70 million tons, while the Marquette, Menominee and Gogebic ranges each produce 4-5 million tons a year.

CHART 7—TACONITE PROJECTS ON THE MESABI



LAKE SUPERIOR'S rugged north shore is the site for two new ore ports and a huge taconite plant. Forty miles inland, across a rocky, pine-covered wilderness, rises a low ridge of hills. They mark the Mesabi range where additional taconite plants and facilities are under construction at Aurora, Babbitt, and Mountain Iron.

In other words, manufactured iron ore probably will soon be a bigger supplier on the ore market than any individual range except the Mesabi itself.

Taconite Reserves

It should be noted that while immense tonnages of material on the Mesabi range are called taconite, only a fraction of it can be commercially used. That's because the massive formation is a layered collection of many different grades of taconite.

Some layers are rich in magnetite, while others are practically devoid of it. In some layers the minerals are relatively coarse-grained; in others they are so fine that no amount of grinding can free the minerals from each other. Costs of processing any but the best grades of taconite would be completely prohibitive under present methods.

The western 30 to 40 miles of the range are almost without magnetite, but along the eastern and central Mesabi there are two or three good-sized zones of relatively rich magnetic taconite similar to that described earlier. From these zones will come the raw material for the new plants.

Thus, while the overall taconite reserves are almost limitless, only those particular reserves from the richer magnetic layers, and within a few hundred feet of the

surface, are of any commercial importance with present technology and price relationships.

Based on this more conservative picture, usable taconite reserves have been estimated at about 5 billion tons.* That would be enough to produce 1.7 billion tons of concentrates which represents about as much iron as all the ore shipped in the history of the Lake Superior iron ranges.

*Published estimates of Professor J. W. Gruner, University of Minnesota.

Part II—OTHER LAKE SUPERIOR RANGES

The Mesabi is not alone in new programs. The first of two plants designed to process the jaspery, iron-bearing rocks of Upper Michigan is now being built on the Marquette range. Though production from these facilities will not be as great as tonnages planned for the Mesabi, in percentage terms they represent an equally important addition to existing mine output. Significant, too, is the fact that methods worked out for these plants will help to solve one major problem—the commercial processing of iron-bearing rock that is nonmagnetic.

The iron ranges of Wisconsin and Upper Michigan have immense tonnages of iron-bearing rock similar in some ways to taconite. There are important local variations in the ranges, however, that will affect commercial possibilities.

First, the eastern ranges are narrower and steeper than the Mesabi. More intense earth movements once tilted the rock layers of these ranges steeply on end, as diagrammed in Chart 8. As a result, the ranges appear to be narrower belts on the map, and for the same thickness of formation smaller tonnages are available near the surface.

Some are too narrow to mine by open pit methods. Since underground mining costs are roughly three to four times those of open pit operations, many of these steeper formations are not now practical sources of raw material for manufactured iron ore.

Second, most of the iron oxide on these ranges is in the form of hematite. The magnetic separation process used on Mesabi taconite will not work on these rocks, and alternative processes are in general more expensive.

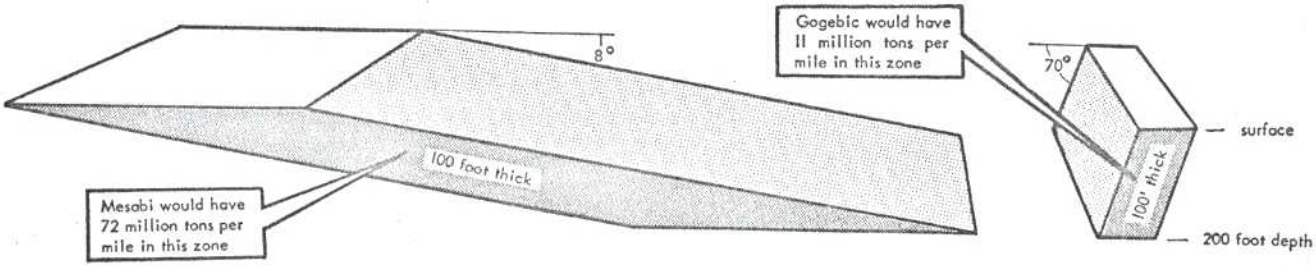
On the other hand, there are some localities where the rock is richer in iron than Mesabi taconite and where grinding will be less costly because the rock is softer. In addition, the eastern ranges are closer to their markets.

Projects On The Marquette

The Marquette range is probably the most important of the Michigan-Wisconsin ranges. It has at least three locations where the rock formation is exposed enough to permit large scale open pit operations. They are indicated on Chart 9.

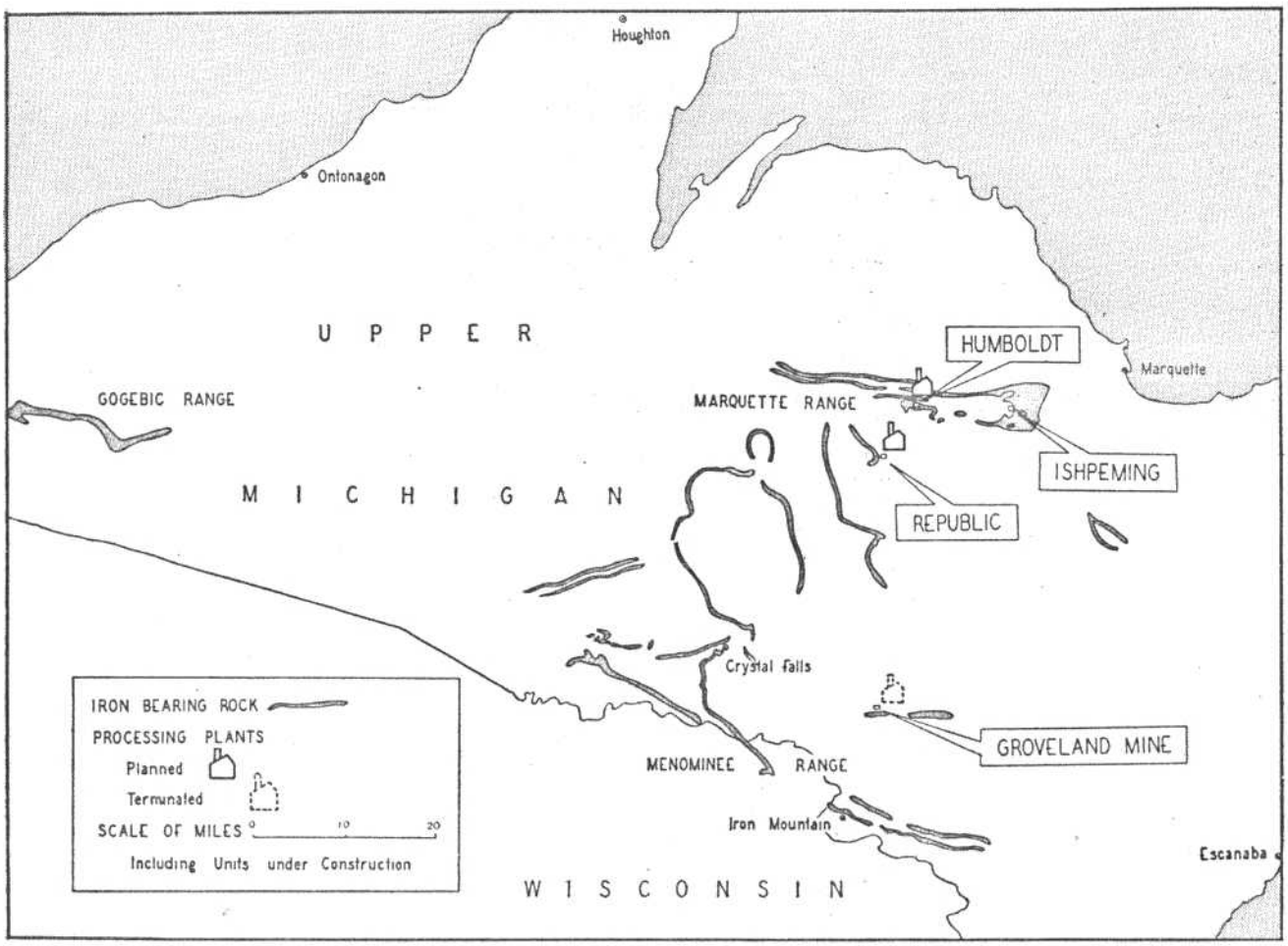
One extensive type of iron-bearing rock on the Marquette is called "jaspilite." It is distinguished by alternating bands of silver-grey hematite and a rust-colored quartz called "jasper." At Humboldt, Michigan, the first commercial plant to handle this kind of material is under construction. The Humboldt Mining com-

CHART 8 — COMPARATIVE SLOPES OF MESABI AND GOGEBIC ROCK LAYERS



COMPARABLE 100-foot sections from the Mesabi and Gogebic ranges illustrate why gently sloping formations of the Mesabi offer greater amounts of material accessible to surface operations. Most parts of the eastern Lake Superior ranges (Marquette, Menominee, and Gogebic) are more or less steeply sloping.

CHART 9—PROJECTS BASED ON IRON-BEARING ROCKS OF UPPER MICHIGAN



TWO concentrating plants are planned for the Marquette range of Upper Michigan. One plant is already under construction at Humboldt, while a second will be started sometime during 1953 at Republic. Although jaspilite to be used at these plants is nonmagnetic, it is somewhat softer and richer in iron than taconite.

pany* is clearing ground alongside re-routed U.S. highway 41 for the first concentration plant outside the Mesabi area.

The hematite-jasper rock has some features that recommend it over taconite. It runs higher in iron (about 33 percent), and is easier to quarry and crush by virtue of its lack of silicates. Because of its coarser grain size, grinding need only be carried to 8-10 thousandths of an inch compared with the 3-5 thousandths of an inch required for taconite. All of this will help to offset the relatively higher separation costs.

The first unit of the Humboldt project will produce 200,000 tons of concentrate a year and is scheduled for completion in 1953. By 1956 a second unit of that size should be operating, bringing the plant's capacity up to 400,000 tons a year.

*Owned jointly by Cleveland-Cliffs Iron Company and Ford Motor Company.

Processing Jaspilite

Processing of jaspilite is in principle the same as that for taconite. The rock must be finely ground to loosen hematite particles from the other minerals, and the hematite must then be sorted out.

There are a number of ways that could be used to separate the hematite. One is called "flotation" and depends on the fact that tiny crystals of hematite will cling to bubbles in certain kinds of frothy solutions, while silica and other minerals will sink. Other techniques, called "gravity" separation and "density" separation,

rely on the great difference in weight between iron and silica. With the aid of special equipment the hematite can be separated from the lighter silica minerals. Most likely a combination of these techniques will be used.

Republic, Michigan, is the site of Cleveland-Cliffs' second jaspilite plant on the Marquette range. Construction is expected to begin early in 1953 toward an initial capacity of 400,000 tons a year. Portions of the iron formation in this locality, a banded rock of jasper and silvery hematite, run 36 percent to 38 percent iron. Deposits are similar to those at Humboldt, but much more extensive. Plans are now under consideration for a development of up to 1,500,000 tons per year.

In the Ishpeming-Negaunee area the iron formation outcrops extensively (some 20 square miles) and offers a good potential source. So far no plans for development of these deposits have been announced. Cleveland-Cliffs, the largest operator on the Marquette, has done research on the formation. Jones and Laughlin Steel Company also has a laboratory at Ishpeming for the study of this material and has acquired deposits both in Michigan and Ontario.

Tests On The Menominee

The Menominee range is complex and less can be said about the potential of this area than most other ranges. One thing that can be said, however, is that a number of its surface exposures (the thin strips that appear on the map) are unsuitable: some too fine grained, too narrow, too lean in iron, too high in impurities or too thickly covered with glacial drift to be used.

Therefore, though deposits of iron-bearing rock over the whole range are quite large, most of them are unsuitable for commercial processing in the near future.

Among the localities offering abundant open pit material is the Felch district north of Iron Mountain. It was tested during 1952 by the M. A. Hanna Company at the old Groveland mine. A small pilot plant was constructed which ground the rock to a relatively coarse 16 thousandths of an inch and separated hematite from chert by a combination of flotation and gravity methods.

The plant itself was set up primarily to gain engineering information and has now been torn down after completion of the initial tests. The data would, of course, serve as the basis for any commercial development in the future, but for the present no plans have been made.

Prospects On The Gogebic

Most of the iron ore now mined on the Gogebic comes from the part located in Michigan, though the iron formation itself stretches some 45 miles into Wisconsin.

The range is well explored, and it is known that substantial tonnages of iron-bearing rock quite similar to taconite exist. However, the material has some disadvantages that restrict its usefulness.

The iron formation is steeply sloping (about 70°) so that the outcrop is narrow compared to the Mesabi. Only thin widths of the formation appear to be suitable for concentration. The eastern part of the range is heavily covered by glacial deposits. These conditions preclude the use of much of the iron formation simply because of the prohibitive expense of underground mining.

Another difficulty arises from the physical nature of the iron-bearing rock. First, its iron content is not predominantly magnetic, implying more expensive processing. A second feature is that the material is generally fine-grained, so the Gogebic has none of the advantages of coarse grinding that can be cited for iron formations on parts of the Marquette range and the Felch district.

Some laboratory tests have been run by the U. S.

TABLE 1—SUMMARY OF TACONITE AND RELATED PROJECTS ON LAKE SUPERIOR RANGES

Company	Location	Plant Capacity (Tons Per Year)	
		Now Operating	Maximum Planned
	Mesabi Range		
Reserve Mining Company	Babbitt—Beaver Bay, Minnesota	300,000	10,000,000
Erie Mining Company	Aurora, Minnesota	200,000	10,500,000
Oliver Iron Mining Division	Virginia—Mountain Iron, Minnesota	——	500,000
	Marquette Range		
Humboldt Mining Company	Humboldt, Michigan	——	400,000
Humboldt Mining Company	Republic, Michigan	——	400,000

Bureau of Mines, however, that suggest the range has slight possibilities. There are no indications of development in the near future.

Of the two smaller Minnesota ranges (Cuyuna and Vermilion) neither is under important consideration at this time. For reasons such as fine grain size, steeply sloped formations, heavy glacial cover or absence of magnetite, these ranges are relatively unattractive for developments similar to those now taking place on the Mesabi.

Part III—ECONOMIC IMPLICATIONS

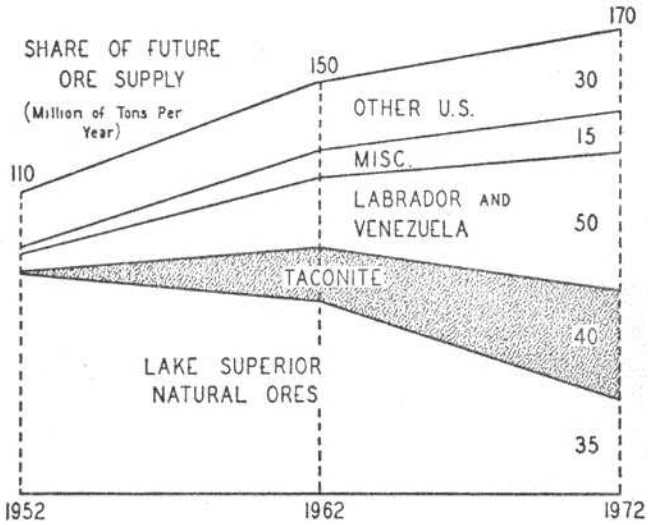
Investment in commercial facilities to manufacture high grade iron ore from iron-bearing rock is now a fact for two district iron ranges and a future possibility for others. The Mesabi's easily accessible reserves are large enough to nominate it as the major center of developments to come. But the Marquette range, where the first commercial attempt on nonmagnetic sources is now being made, is also important. (See Table 1.)

Competitive Ability To Limit Industry's Size

The taconite industry on the Mesabi has possibilities of going beyond the 20 million tons a year capacity now expected for the two big commercial plants.

It is felt that taconite will be one of the chief factors in making up the difference between the expected growth of iron ore demand and decline in output of Mesabi's natural ores. (The gap which taconite will help to fill may run as high as 80 million tons a year by the end of two decades.) Just how much of the difference will be met by taconite depends on how the costs of its product compare with those of the important competing sources, particularly Labrador and Venezuela.

CHART 10—POSSIBLE FUTURE ORE SOURCES



If the new industry is successful in its task of paring costs, it may double its presently projected size, as suggested in Chart 10.

This, of course, must be regarded as just one possibility. Various estimates of output in two decades' time are as high as 60 million tons a year and as low as 20 million.

The actual division between the domestic taconite and foreign supplies will depend on how well each can compete—tempered probably by defense considerations. It is largely a matter of relative costs.

Costs Are Critical

Costs are a critical problem for taconite. Mining costs are inevitably high—each ton of product must bear the mining costs of three or four tons of crude rock. In addition, power, fuel, and water requirements for processing steps are great.

Only if all aspects of cost are kept as low as possible can this new industry expect to be competitive with other sources of high grade ore concentrated by nature.

Technical advance can have a substantial effect on operating costs through the introduction of more efficient machines and methods.

Capital costs are important too. The large plant investments mentioned previously will have to be charged off against the product turned out by the plants.

One of the important factors fostering the present development was Minnesota's 1941 law limiting taxes on taconite operations. The Minnesota tax on taconite concentrate will probably be no more than 6c to 10c a ton in contrast to the high state tax on natural iron ore that in 1949 averaged 57c a ton.

Prospects are good that the taconite industry can improve its competitive position. The tremendous sums spent on research and development and the intensive work carried on by the companies and institutions* that made commercial taconite a possibility in the first place are reasons for optimism.

But until more business experience lies behind both taconite and the new foreign sources, the ultimate size of the taconite industry will remain as indefinite as today's varying estimates indicate.

High Costs Offer Challenge To Stable Operations

The taconite industry will be very important to the iron range area and the facilities which serve it. On the Mesabi, for example, it appears that taconite processing will more than offset any loss in employment that might result from the gradual decline expected in production of natural iron ores over the next 25 years. Within 10 years, 6,000 people may be employed by the taconite industry in Minnesota—almost two-thirds of the number of people now employed on the "direct-shipping" natural ores.

Long Future Ahead

From the standpoint of length of operations, the presently usable reserves of taconite are sufficient to keep a very large industry going for several decades. (See Table 2.)

Laboratory accomplishments of today may extend reserves indefinitely through the use of other kinds and grades of iron-bearing rock. For example, nonmagnetic taconite can be converted to magnetic taconite through controlled heat treatment. By the time magnetic taconite reserves have been exhausted, it is possible that new techniques such as this will open the very large nonmagnetic reserves to commercial production.

Slumps May Hurt

Until more cost data are available, it is impossible to forecast the impact on the taconite industry of slumps in demand for iron ore. Based on trends in population and use of raw materials in the United States, official expectations are for a long term growth in steel consumption—hence demand for iron ore—of very substantial proportions.*

*Such as the University of Minnesota mines experiment station which has played an important role in past developments.

TABLE 2—TONNAGES OF IRON-BEARING ROCK ON LAKE SUPERIOR RANGES*

(Estimates in Millions of Tons)

	Crude Rock	Product (64% Iron)
Mesabi magnetic	5,200	1,700
Mesabi nonmagnetic	15,000	5,000
Marquette	1,600	600
Menominee	1,200	400
Gogebic	1,200	400
Total four ranges	24,200	8,100

*These figures include potentially "usable" rock within 200 feet of surface. Figures are highly tentative, except possibly for Mesabi. Michigan-Wisconsin figures not all open pit material. Table based on published estimates of J. W. Gruner, University of Minnesota; and F. G. Pardee, Michigan Geological Survey.

Such conditions imply the steady employment of both low- and high-cost sources of iron ore. In the event of severe reductions in demand, however, it must be recognized that high-cost sources such as taconite may be at a disadvantage. (The rich, natural ores of Labrador and Venezuela are not necessarily "low-cost" in this sense.)

One aspect of stability promised by the new facilities arises from the fact that taconite plants are designed for continuous year-round operation. This should tend to eliminate seasonal variations in employment that have been a part of some open pit operations of the past.

Conclusions

The general level of economic activity on the iron ranges of the district can be expected to rise rather than decline with the coming readjustments in ore supplies. This is quite significant, since iron mining supports directly or indirectly a good share of the population in sections of the Ninth federal reserve district.

The new industry has good possibilities for growth, and an extremely long potential "life." Important to the banks and commercial operations in the area is the prospect that the taconite industry will contribute to a steady year-round level of business activity.

*See report of President's Materials Policy Commission, June 1952.

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