UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

BUREAU OF MINES
R. R. Sayers, Director

War Minerals Report 186

SCAPPOOSE MINE
COLUMBIA COUNTY, OREG.

Iron

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The War Minerals Reports of the Bureau of Mines are issued by the United States Department of the Interior to give official expression to the conclusions reached on various investigations relating to domestic minerals. These reports are based upon the field work of the Bureau of Mines and upon data made available to the Department from other sources. The primary purpose of these reports is to provide essential information to the war agencies of the United States Government and to assist owners and operators of mining properties in the production of minerals vital to the prosecution of the war.

WAR MINERALS REPORT

UNITED STATES DEPARTMENT OF THE INTERIOR — BUREAU OF MINES

W.M.R. 186 - Iron April 1944

SCAPPOOSE MINE

Columbia County, Oreg.

SUMMARY

The Scappoose iron-ore deposits in Columbia County, Oreg., were explored to some extent during the 1890's and early 1920's by churn drilling, trenching, and test pitting. The demand for iron ore for war purposes has revived interest in these deposits, and in 1942 the Bureau of Mines carried out extensive exploration. The work indicated 4,000,000 long tons of iron ore, 2,140,000 and 765,000 long tons of which are estimated to be recoverable by underground and opencut mining methods, respectively. The ore will average about 19.7 percent moisture, 39.1 percent iron, 0.0367 percent sulfur, 0.58 percent phosphorus, 0.47 percent manganese, 4.30 percent silica, and 3.58 percent alumina. From the recoverable tonnage indicated, about 1,160,000 long tons of pig iron high in phosphorus can be produced, the amount depending on the method employed to remove it.

Because of the relatively small tonnage of ore, the means of reduction would be limited to small units, such as electric furnaces. The limited size of the ore bodies would not justify a blast

furnace with a capacity of 1,000 tons, or even 500 tons, of pig iron per day, as such a furnace would deplete the recoverable ore reserve within 3½ to 7 years. The capital cost for such equipment could not be returned from the limited ore reserves.

The pig iron made from this ore would have a high phosphorus content and would not meet usual specifications for steel making. Any process to remove the phosphorus would increase the cost of production, possibly above the competitive price range. Possibly this ore could be utilized directly in the manufacture of cast-iron pipe at a plant adjoining the furnace. Such an industry existed in the Portland area previous to 1894, and at present there is a greater demand in this region for cast-iron pipe than existed from 1867 to 1894.

The capital cost of development, mine equipment, and a plant for manufacturing cast-iron pipe is estimated at $1,500,000. The indicated recoverable ore reserves are sufficient for about 70 years of production at a rate of 50 tons of pig iron per day.

INTRODUCTION

The Oregon limonite deposits have been known for many years, and iron has been produced commercially from one deposit 2½ miles west of Oswego, Oreg. A blast furnace in Oswego (8 miles south of Portland) is reported to have operated from 1867 to 1894, but the total tonnage treated is not known. Pig iron and cast-iron pipe were manufactured by the Oregon Iron Co. and its successors.

The Scappoose iron-ore deposits in Columbia County, 3 to 16 miles northwest of Scappoose, were discovered about 1890, and it is possible that a small quantity of ore was shipped to the Oswego plant before operations ceased. These deposits are scattered over an area of about 54 square miles in Ts. 3, 4, and 5 N., Rs. 2 and 3 W., Willamette meridian. In order of their importance with respect to ore reserves, they are as follows: Colport-Charcoal, secs. 3 and 10, T.3 N., R.2 W., and sec. 34, T.4 N., R.2 W.; Ironcrest, sec. 35, T.4 N., R.3 W.; Ladysmith, secs. 25 and 26, T.5 N., R.3 W.; Bunker Hill, sec. 31, T.5 N., R.2 W., and sec. 6, T.4 N., R.2 W.; and Hill 600, sec. 27, T.4 N., R.2 W., Willamette meridian.

In recent years considerable interest has been shown by public agencies and private persons in the development of iron industries in the Northwest, as there is an increasing demand for various iron and steel products. The availability of cheap power had stimulated interest in the investigation of the Scappoose iron deposits as a source of ore for a reduction plant in the vicinity of Scappoose, Oreg.

A preliminary examination of this deposit was made by an engineer[1] of the Bureau of Mines in 1941, and an extensive exploration program was conducted by the Bureau from January to September 1942. Preston Hotz, of the Federal Geological Survey, cooperated in interpreting the geology and in logging holes. Exploration work comprised trenching, test pitting, hand-augur drilling (several thousand feet), churn drilling (7,000 feet), and rotary bucket drilling (6,000 feet).

HISTORY

The iron industry in Oregon has had an interesting history dating back to about 1867. The Oregon Iron Co. began operation of a furnace plant at Oswego to treat limonite ore obtained from a deposit 2 to 20 feet thick in the vicinity.

Pig iron and cast-iron pipe were produced from these high-phosphorus and high-sulfur ores by this company and its successors over a period of 27 years. Operations were finally abandoned in 1895.

Similar limonite ore was discovered in the vicinity of Scappoose in 1890. It is believed that little developing was done until

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1 C. H. Johnson.

about 1918, when an active interest was taken in the Scappoose deposits, which lasted until about 1926. The Oregon Charcoal Iron Co. and its successor, the Oregon Iron Ore Development Corporation, drilled more than 24 churn drill holes, and many cuts were excavated on the Colport-Charcoal deposit. The other deposits in this area also were explored by various operators. This work consisted of drilling about 30 holes on the Ironcrest area by hand tools and test-pitting and trenching on the Ironcrest, Ladysmith, and Bunker Hill properties. In addition, the Bunker Hill deposit was drilled by hand augers and prospected by a tunnel driven 144 feet.[2]

Following this period of activity, exploration ceased until the Bureau of Mines began its project in 1942.

PHYSICAL FEATURES AND COMMUNICATIONS

The land surface is generally rugged and has been cut by erosion and streams flowing northeast into the Columbia and northwest into the Nehalem and Clatskanie Rivers. The divide between the Columbia and Nehalem River rises to an altitude of about 2,000 feet. The steep canyon walls are covered by a mantle of alluvium that almost completely covers the underlying rocks. At one time the area was covered by a heavy stand of timber, which, with the exception of a few patches, has been removed by logging operations. The stump areas are now heavily covered by thick undergrowth and small stands of second growth fir and other trees.

The climate is generally mild, with frequent rains, throughout the winter and spring. Summers are usually hot and dry, and in the fall there are alternating wet and dry periods. Snow is uncommon in this region.

Both the Colport-Charcoal and Ironcrest properties are accessible by a logging railroad maintained by the Clark & Wilson

2 Oregon Bureau of Mines and Geology, The Mineral Resources of Oregon: Vol. 3, No. 3, May 1923.

Lumber Co. This railroad extends from Chapman Landing on the Columbia River, on the Willamette Slough, up the North Fork of Scappoose Creek and is connected to the Portland-Astoria branch of the Spokane, Portland & Seattle Railroad at Scappoose. This latter railroad extends from Portland, through Scappoose, to Astoria, Oreg. A large portion of Columbia County is interlaced with abandoned logging railroad grades that could again be put into serviceable condition at moderate cost.

Scappoose, about 25 miles north of Portland, is connected with the latter city by U. S. Highway 30. Several good, hard-surfaced State and county roads and numerous logging and truck roads make the iron areas fairly accessible, at least during dry weather.

LABOR

Manufacturing in this area is confined largely to the processing of wood and wood wastes. In addition to several sawmills, there is a pulp and a kraft-paper mill, a nationally known wallboard factory, a wood-preserving establishment, and several smaller wood-processing plants. The 45 manufacturing establishments in operation in 1939 employed 2,607 workers with an annual payroll of \$3,626,535.[3] Most of the manufacturing activity of Columbia County is along the Columbia River, chiefly at St. Helens, 7 miles from Scappoose. There is a large and very modern sawmill at Vernonia, which is near the iron-ore deposits. The largest and what may be the last extensive logging operation in the county is the Clark & Wilson Co. in the immediate vicinity of the iron-ore deposits. This operation employs more than 250 men.

A wage scale of \$7 to \$8 a day for common labor and \$8 to \$10 or more a day for semiskilled and skilled labor now prevails here. Before the war, the usual wage was \$5 a day for common labor and \$7 a day for skilled labor. It is probable that over a 20-year period the average wage scales would be near the latter figures.

3 U. S. Bureau of Census, Census of Manufacturers: 1939.

At present, housing, board, and room are inadequate for a large number of men. A housing program would be required if operations are to begin now or in the near future.

PROPERTY

Most of the land containing iron ore is privately owned; the rest is owned by the United States Government and Columbia County. These ownerships include both surface and mineral rights.

The Colport-Charcoal deposit is the largest of the iron areas, but the drilling indicated that it is comprised of four separate portions designated areas 1, 2, 3, and 4. Likewise, the Ladysmith deposit consists of two and the Bunker Hill of four separate areas. Hill 600 consists of a single deposit. Table 1 shows the total acreage contained in the deposits and the ownership.

TABLE 1

	Acreage and ownership				
	Oregon Iron Development Co.	Private	Columbia County	U. S. Govt.	Total acreage
Colport-Charcoal. .	92	119.0	2.8	0.2	214.0
Ironcrest	--	15.0	--	--	15.0
Ladysmith	--	13.4	--	--	13.4
Bunker Hill	--	4.4	--	0.7	5.1
Hill 600.	--	6.0	--	--	6.0
	92	157.8	2.8	0.9	253.5

Some of these areas are under lease to logging companies. The iron areas are not under cultivation and, owing to their rugged topography, would seem to have little value as farming land. No mining equipment is on the properties, and little exploring has been done.

GEOLOGY

The iron deposits are in the Coast Range of mountains, which were formed by a broad upward fold of the Tertiary formations, whose axis runs in a northerly direction.[4] The rock formations in this part of Columbia County are mainly sandstone, shales, and

4 Work cited in footnote 2.

basaltic lavas, all of Tertiary age. The basalt, lying unconformably on the sedimentary formations, consists of several series of flows. Erosion, though deep, has barely reached the underlying sandstone and shales in much of the area. It is only in the western part of the area, near the divide between the Columbia and Nehalem-Clatskanie drainage, that much of the lava cover has been removed, so that it occurs largely as hill and ridge capping. Minor folds and some faulting have disturbed the sedimentary rocks to a minor extent.

The iron ore occurs in some places as a blanket formation between weathered basalt flows and in others between sandstone and altered basalt.

There is considerable evidence that much of the ore has been moved by streams and deposited in depressions, thus forming a natural concentrate. Some of it may be a chemical precipitate (bog iron), but there are features, even in the large blanket of the Colport-Charcoal deposit, that strongly indicate transportation and deposition. The original source of the ore may have been precipitation in bogs or chemical decomposition and leaching of the basalt followed by transportation by streams and concentration in depressions on the surface.

The ore originated during an interruption in the volcanic sequence, during which there was strong chemical weathering and erosion. Shortly after the ore was deposited, it was covered by a thin bed of tuffaceous material, probably in part carried in by streams, and this was followed by another series of basalt flows that buried and preserved the deposits.

The ore bodies of the Colport-Charcoal deposit are broadly lenticular and are thin and pinch out abruptly on their edges. There is no assurance at any place that the "blanket" of ore is continuous. Drilling showed that there are barren channels in the blanket where streams received some of the ore prior to the extrusion of the preserving lava capping. There are, however, many deposits of shot ore throughout the region, including Ironcrest, Ladysmith, and Bunker Hill. These "shot" deposits are irregularly sloped blankets on the surface and consist of loose, limonitic concretions, or, more commonly, limonite concretions bound together in a hard limonitic matrix. They probably originated on the surface as products of weathering and leaching of the basalt.

THE DEPOSITS

The Colport-Charcoal deposit, which lies at an altitude of 450 to 900 feet, is a blanket formation containing hard and soft limonite ores. These two types of ore are almost identical in composition and occur in almost equal proportions. This deposit is not a continuous bed but is composed of four separate ore bodies that dip 2° to 10° to the northeast and vary in thickness from 2 to 14 feet. The depth of overburden is from 3 to as much as 150 feet in some places; the average depth is estimated to be 80 feet.

The Ironcrest deposit lies on a ridge that trends northeast. Although the slope of the ridge to the southwest is gradual, it is precipitous at its northeast extremity. The elevation there declines from 2,050 to 1,750 feet in a lateral distance of less than 700 feet. The shape of the ore body suggests a stream channel filling, and the ore consists of a soft, yellow limonite mixed with limonitic concretions and bands of hard, nearly black limonite. In the extreme western part of the area, the ore rests on a pebbly, tuffaceous sandstone and is overlain by basalt, whereas, the eastern portion of the deposit lies between altered basalt flows. Following the periods of iron deposition and basalt flows, the area may have been uplifted, and later erosion may have carved away all but the short section of the channel that now remains. Thickness of the ore ranges from 2 to 20 feet, whereas the overburden is 3 to 50 feet thick.

The Ladysmith deposit is similar to the Ironcrest in that it is a stream-bed deposit and the ore consists of limonitic concretions cemented with iron oxide. However, the deposit consists of two separate areas, the smaller of which lies at an elevation about 50 feet higher than the larger one. It is possible that these two areas are remnants of one stream channel. The overburden is 6 to 49 feet thick and the ore body 2 to 17 feet thick. The larger ore body lies on a hillside, which slopes 6° southeast. The smaller deposit lies on a wide, flat ridge. The ratio of thickness of overburden to ore ranges from about 1:1 to 5:1, being higher where the ore body is 2 feet or less in thickness.

The Bunker Hill deposit also appears to be a stream-channel filling of limonitic concretions cemented by iron oxide. The ore body has been separated into four small areas comprising about 5 acres. The ore bed is 0.5 to 9.5 feet in thickness, whereas the thickness of the overburden ranges up to 70 feet.

A small isolated deposit in the vicinity of the Colport-Charcoal areas, known as Hill 600, consists of a relatively thin bed of limonite ore.

High-grade hematite float was found in the Alder Creek area in sec. 8, T.4 N., R.2 W., Willamette meridian. The float consisted of pieces of high-grade hematite that varied from a few inches to a foot or more in their largest dimensions. Prospecting this area by bulldozing and churn drilling failed to locate any similar ore in place.

EXPLORATION BY BUREAU OF MINES

A control map was made of the old workings, consisting of trenches, pits, and adits; and as exploration progressed, the ore deposits were outlined.

The deposits were explored by churn, rotary-bucket, and hand drilling, trenching, bulldozing, and cleaning out old workings.

Machine drills were employed in deep holes and where basalt overburden could not be penetrated by hand augers. Hand augers were employed only in shallow holes at the peripheries of the ore bodies, where the overburden consisted of soil and clay; churn drills were usually used on holes 100 feet or more in depth and also on shallow holes where the overburden consisted of hard basalt. Rotary-bucket drills were used on holes less than 100 feet deep and where the overburden could be penetrated by them.

A summary of footage and number of holes drilled by machine drills in each area is given in table 2.

TABLE 2

	Rotary-bucket		Churn	
	Footage	Holes	Footage	Holes
Colport-Charcoal.	4,052	58	4,808	43
Ironcrest	661	28	1,012	23
Bunker Hill	1,684	39	--	--
Ladysmith	1,030	27	--	--
Alder Creek	--	--	475	5
	7,427	152	6,295	71

The above table does not include several thousand feet of hand-auger holes also drilled. Hill 600 deposit was prospected with auger holes, test pitting, and trenching.

Old cuts were cleaned out to expose the edges of the ore body, and new cuts were made at such places as could not be drilled by hand augers or where a bulldozer could not be used. Bulldozers were used, where possible, to expose the cross section of the iron ore at the edges of the deposit, and cuts thus made were usually 60 to 80 feet long.

ORE RESERVES

It was difficult to drill holes on uniform grid patterns owing to the dissected topography and steep slopes. To estimate the tonnage of iron ore, areas were divided into segments, each surrounding a drill hole, and the total cubic content of each individual deposit was obtained by summation of the iron-ore content of all the segments.

The indicated tonnages of iron ore, the area in acres, and the minimum, maximum, and average thicknesses of ore and overburden for each property are given in table 3. The average analysis of each deposit was calculated from the analyses and thickness of iron ore in each hole and weighted with the area allotted to each hole. The assay analyses are given in table 4.

TABLE 3. - Thickness of iron ore and overburden and indicated iron-ore tonnage

Deposit	Areas	Acreage	Iron-ore thickness Min.	Iron-ore thickness Max.	Iron-ore thickness Ave.	Overburden thickness Min.	Overburden thickness Max.	Overburden thickness Ave.	Indicated long tons of ore
Colport-Charcoal	1	31	2.0	14.0	7.2	3	84	60	578,500
	2	47	2.0	14.0	5.0	3	106	70	608,900
	3	77	2.0	14.0	6.0	3	154	90	1,196,400
	4	59	2.0	7.0	4.7	3	151	90	718,700
		214							3,102,500
Ironcrest	1	15.0	2.5	20.0	12.0	3	50	24	464,200
Ladysmith	1	3.2	2.0	17.0	7.3	7	23	13	60,700
	2	10.2	6.0	15.5	12.1	6	49	21	319,600
		13.4							380,300
Bunker Hill	1	1.1	2.0	9.5	5.2	1.0	18.0	10.0	14,200
	2	.5	3.0	4.0	3.5	.0	.0	.0	4,400
	3	2.0	1.5	9.0	4.1	3.0	31.0	18.0	21,400
	4	1.5	2.0	5.0	3.1	21.0	70.0	50.0	12,500
		5.1							52,500
Hill 600	1	6.0	2.0	5.2	3.2	5.0	60	30	50,000
Total		253.5							4,049,500

TABLE 4. - Average analyses

Natural basis, percent

Area	Moisture	Ignition loss	Fe	S	P	Mn	SiO_2	Al_2O_3	TiO_2
Colport-Charcoal. .	19.5	10.5	39.0	0.0226	0.623	0.50	4.07	3.65	--
Ironcrest. .	20.8	10.28	39.36	.066	.362	.26	5.46	1.80	--
Ladysmith. .	19.5	10.04	39.88	.103	.557	--	4.58	3.18	0.32
Bunker Hill.	21.8	9.90	35.85	.131	.571	--	3.84	4.35	--
Hill 600 . .	20.0	8.80	39.8	.027	.71	.52	4.61	6.25	0.32
Average. .	19.7		39.1	.0367	.587	.47	4.28	3.58	

TABLE 4. - Average analyses - Continued

Dry basis, percent

Area	Moisture	Ignition loss	Fe	S	P	Mn	SiO_2	Al_2O_3	TiO_2
Colport-Charcoal. .	--	13.04	48.4	0.0280	0.7739	0.62	5.05	4.53	--
Ironcrest. .	--	12.98	49.70	.0833	.4570	.33	6.89	2.27	--
Ladysmith. .	--	12.47	49.5	.1279	.6919	--	5.69	3.95	0.40
Bunker Hill.	--	12.66	45.8	.1675	.7301	--	4.91	5.05	--
Hill 600 . .	--	11.09	49.8	.034	.887	.65	5.77	7.81	--
Average. .			48.6	.046	.73	.58	5.33	4.26	

The total iron-ore reserves in the Colport-Charcoal, Ironcrest, Ladysmith, Bunker Hill, and Hill 600 areas are estimated to be 4,049,000 tons. Average assays on a dry basis for these ore bodies are as follows: 48.6 percent iron, 0.046 percent sulfur, 0.73 percent phosphorus, 0.582 percent manganese, 5.33 percent silica, and 4.26 percent alumina. Seventy-six percent of the total indicated ore reserves is in the Colport-Charcoal deposit. The percentage of iron content of this deposit is about the same as that in the other deposits, but the percentage of sulfur content is lower, and the phosphorus content is higher.

PLANS FOR OPERATION

Several plans have been proposed to exploit the Columbia County iron ores, although none have materialized. One project, developed in 1939 by D. H. Botchford, involved the use of this ore in an electric pig-iron operation. Botchford organized the Sierra Iron Co., contracted for Power from the Bonneville Power Administration, made arrangements for delivery of the ore, and began work on a plant site at Vancouver, Wash. It was planned to use the high-phosphorus iron in an allied cast-iron-pipe plant at Portland and Los Angeles. The project was stopped by Botchford's death, but efforts to revivé it were made in 1940-41 by D. Earle Stewart, who held title and leases on sections of the Columbia County field. Stewart's project led up to the request for the Bureau of Mines' investigation.

The Oregon Iron Ore Development Corporation, successor to Oregon Charcoal Iron Co., with offices in Portland, has also been active in an effort to interest capital in developing a project based upon its iron-ore holdings.

Development of the various projects proposed has been handicapped by lack of conclusive knowledge of the ore reserves. The high phosphorus content of the ore had a deterring effect, particularly on those projects that involved the sale of pig iron to foundries or for use in a steel plant.

MINING

Some of the iron-ore deposits, overlain by relatively small amounts of overburden, can be mined by opencut methods. Such operation would apply to the major portions of the Ironcrest, Ladysmith, and Bunker Hill deposits. The Colport-Charcoal deposit, on the other hand, is overlain by basalt having a thickness in some places of 150 feet. Calculation of average depth of overburden, as given in table 3, shows that areas 1, 2, 3, and 4 are overlain by 60, 70, 90, and 90 feet of overburden, respectively. These deposits must be mined by underground methods, as the iron-ore beds are only 4.7 to 7.2 feet thick.

OPENCUT MINING

The most favorable deposit for opencut mining would be the Ironcrest area. Average thickness of ore is about 12 feet, and average ratio of overburden to ore thickness is about 2.0:1. Along the northern edge, the ratio of overburden to ore, as indicated by drilling, is high and ranges from about 8:1 to 6:1. It is estimated that at least 10 percent of this ore body would not be mined because of the large amount of overburden in certain portions of the area.

Thickness of the iron-ore bed in the smaller area (No. 1) of the Ladysmith deposit decreases to 2 feet. Probably about 50 percent of this ore body would be suitable for opencut mining. The larger area (No. 2) has an iron-ore bed about 12 feet in average thickness and a ratio of about 1.7 overburden to 1 iron ore. However, in three holes the ratio was higher, ranging from 3.5:1 to 5:1. It is estimated that the maximum recoverable tonnage will not be more than 90 percent of the total indicated ore reserve. Almost all of the Bunker Hill ore bodies — 1 and 2 and about 50 percent of 3 — could be mined by opencuts, whereas all of 4 is unsuitable for mining owing to the thin iron-ore bed and relatively great thickness of overburden.

A summary of total indicated tonnage, ratio of overburden to thickness of iron ore, and estimated tonnage recoverable by opencut methods is given in table 5 by areas.

TABLE 5

	No. of area	Ratio of overburden to iron ore	Total tonnage, long tons	Percent recoverable	Indicated tonnage recoverable, long tons
Ironcrest.	-	2.0:1	464,200	90	417,700
Ladysmith.	1	1.8:1	60,700	50	30,350
Ladysmith.	2	1.7:1	319,600	90	287,600
Bunker Hill. . . .	1	1.9:1	14,200	100	14,200
Bunker Hill. . . .	2	0	4,400	100	4,400
Bunker Hill. . . .	3	4.4:1	21,400	50	10,700
Total and average.		1.93:1	884,500	87	764,950

In calculating stripping and mining costs, volume and weight measurements for the various materials were considered. Numerous pits in iron ore were measured and the contents weighted. It was found that 13 to 16 cubic feet of ore in place was equal to 1 short ton. In considering the ratio of overburden to ore, the cost of stripping and mining is estimated at $0.80 to $0.90 per long ton of ore.

In all probability the iron ore would be hauled to Scappoose for reduction. The Ironcrest, Bunker Hill, and Ladysmith deposits are distant from Scappoose about 10, 12, and 15 miles, respectively. Average haulage distance to Scappoose for the entire recoverable tonnage would be about 12 miles. Average cost of hauling ore, including repair and maintenance of roads and hauling equipment, is estimated at $0.06 per ton mile. Hence, the total cost of stripping, mining, and hauling the ore to Scappoose is estimated to average about $1.55 per ton.

The Hill 600 deposit is of little importance, as the thin bed of ore and relatively great thickness of overburden precludes any economical method of mining.

UNDERGROUND MINING

The Colport-Charcoal deposit, comprising four separate areas, must be mined by underground methods, as the amount of overburden is too great for opencut methods. The average thickness of ore ranges from 4.7 to 7.2 feet, and the average thickness of overburden ranges from 60 to 90 feet.

Although the indicated tonnage in this deposit is about 3,102,500 long tons, it is possible that 10 to 15 percent of the ore may occur in a bed thickness of 3 feet or less, which may not be economical to mine. It is also possible that another 20 percent of the ore would be left as pillars, which would be lost. Of the total indicated tonnage, it is estimated that only about 2,140,000 long tons could be mined.

A room and pillar system or similar method of mining could be used. Laterals could be driven from the main entries, which would divide the ore body into blocks of more or less uniform size. In an area consisting of several blocks, alternate rooms would be mined first, followed as quickly as possible by removal of the pillars.

However, before the best areas can be selected for mining and the location of haulageways and laterals is planned, additional drilling should be done on the Colport-Charcoal deposits, so that development and mining operations can be conducted to the best advantage.

The ore is soft, and little explosive would be required to break it. Broken ore could be moved and loaded into mine cars by scrapers. The ore trains would be moved by battery or trolley locomotives. It is possible that the cost of underground mining of Scappoose ore, including only labor, supplies, and power, would be about $2.32 per ton, and hauling to Scappoose, a distance of 3 miles, would add another estimated $0.18 per ton, bringing the total cost of ore delivered at Scappoose to $2.50 per ton. These are not total mining costs, as taxes, development, and overhead have not been considered. Total costs are given in table 6 under Costs of Operation.

MARKETS

The market for iron in the Pacific Northwest is in the many iron foundries, steel-casting plants, and the three steel mills in Seattle and Portland. All these are heavy users of scrap iron and only minor users of pig iron. The steel mills supply the region with only a part of its rolled-steel products. They roll principally merchant and reinforcing bar, light and some heavy structurals, universal plates, splice bars, and tie plates. The plants, locations, and ingot capacity are as follows:

Company	Location	Annual capacity ingots (gross tons)
Bethlehem Steel Corporation.	Seattle, Wash.	193,000
Northwest Steel Rolling Mills.	Seattle, Wash.	44,000
Oregon Electric Steel Rolling Mills. .	Portland, Oreg.	54,000
		291,000

Previous to 1940, the scrap-iron supply was more than adequate for the existing steel capacity, and large shipments of excess scrap were exported to Japan from the Pacific Northwest. Since 1941, the steel-ingot capacity of the region has been increased from 155,000 gross tons annually to 291,000 gross tons in 1943. War demands upon the Northwest steel plants and shipment of Northwest scrap iron to other consuming areas have reduced the available scrap-supply and created a favorable local market for merchant pig iron. There is a ready market on the west coast for foundry pig iron of suitable quality. If this were produced, operations might later broaden into production of such cast-iron and steel products that do not require heavy capital investment in rolling and finishing equipment.

The building of new steel capacity in the Pacific Northwest, as is now being advocated, would further drain the scrap supply. Such a plant undoubtedly would require a pig-iron unit to supply a substantial part of the metallic charge for the steel furnaces. Use of Scappoose ore for the basic pig iron required by a steel plant would be possible, but the high-phosphorus ore would yield a pig iron with 1 to 2 percent phosphorus. This would have to be considered in determining the methods and feasibility of conversion to steel.

Manufacture of cast-iron pipe, as proposed by D. H. Botchford in 1939, may be feasible. Such an industry existed in this area when Oswego ore was used and probably could be resumed, using the Scappoose ore. The influx of heavy and other industries, with resulting increase in the population of the various towns and cities, indicates a growing need for this product.

BENEFICIATION TESTS

As the ore contained an objectionable amount of phosphorus, preliminary ore-dressing, leaching, and sponge-iron tests were made to determine if the ore as mined could be beneficiated to produce acceptable products for manufacture into pig iron and steel.

Analysis of the large sample submitted, representative of average-grade ore available, showed 53.8 percent Fe, 1.2 percent Mn, 3.8 percent insoluble, 2.0 SiO_2, 2.6 Al_2O_3, 0.08 S, 0.68 P, and 0.05 percent TiO_2.

The iron occurs chiefly as limonite, although there is also present a small quantity of the mineral goethite. Both hard and soft limonite was noted. The hard limonite is present as a lace-like network of small veinlets in the softer variety. Clay minerals are the principal gangue and are distributed uniformly throughout the limonite. No phosphorus minerals were identified.

To determine whether the ore could be beneficiated by washing, a screen analysis and elutriation test was made on ore crushed to 1 inch. The results are given in table 6.

TABLE 6

Product	Weight, percent	Assay, percent			Distribution, percent		
		Fe	P	Insol.	Fe	P	Insol.
+3-mesh.	11.3	54.8	0.69	2.4	11.7	11.9	7.6
-3+10-mesh	18.0	54.5	.75	2.0	18.6	20.7	10.0
-10+20-mesh. . . .	9.1	54.6	.74	2.0	9.3	10.3	5.1
-20+48-mesh. . . .	10.8	53.8	.64	2.4	11.0	10.7	7.3
-48+120-mesh . . .	6.4	53.0	.61	2.6	6.4	6.0	4.7
-100+200-mesh. . .	5.4	52.5	.61	2.8	5.4	5.1	4.3
-200+400-mesh* . .	2.8	52.2	.68	3.6	2.7	2.9	2.7
-400+800-mesh* . .	2.3	51.5	.63	5.0	2.3	2.2	3.3
-800-mesh*	33.9	50.9	.58	5.8	32.6	30.2	55.0
Calculated heads .	100.0	52.9	.65	3.6	100.0	100.0	100.0

* Calculated size range from rate of overflow of elutriation.

The results given in table 6 indicate the friable and slimy nature of the ore. Over one-third of the ore disintegrated into minus 800-mesh slimes when crushed to 1 inch and wet-screened. Comparison of the distribution of iron and phosphorus in the size fractions clearly indicates that the association is so intimate that washing or other ore-dressing methods would prove ineffective as a means of rejecting phosphorus.

Since the screen analysis proved ore-dressing methods would be inapplicable in beneficiating the ore and removing phosphorus, a few preliminary tests were made to determine if the phosphorus could be leached from the ore. When unroasted ore was treated with sulfuric acid, it was not possible to thicken or filter the pulp effectively, owing to its slimy nature. However, after roasting, the ore could be washed and filtered satisfactorily. A sample of the ore was roasted for 1 hour at 950° C. and then agitated for 1 hour with a 5-percent solution of sulfuric acid. The pulp was filtered and washed. The results obtained indicated that although two-thirds of the phosphorus could be leached from the ore with little loss of iron, the residue still contained 0.25 percent phosphorus. The roasted and leached product assayed 62.8 percent iron. Acid consumption totaled 56 pounds sulfuric acid per ton of ore treated.

In addition to these leaching tests, a number of direct smelting tests were made employing various slag combinations and smelting conditions to determine if it was possible to eliminate the phosphorus in the smelting process. Results indicated that only high-phosphorus pig iron could be produced by direct smelting of the ore. The phosphorus analysis of the pig iron made ranged between 0.8 and 1.0 percent phosphorus regardless of test conditions employed.

The possibility of beneficiating the ore and eliminating phosphorus by making sponge iron also was investigated by a few small-scale laboratory tests. Four samples of the ore were crushed and ground to minus 8-mesh, 28-mesh, 100-mesh, and 200-mesh, respectively. Each sample was placed in a hydrogen atmosphere for half an hour at 550° C. and cooled in a reducing atmosphere. The reduced ore was then treated in a Davis-tube wet magnetic separator. The results are summarized in table 7.

The data given in table 7 indicate that phosphorus cannot be eliminated by reducing the ore and treatment in a magnetic separator. Other than the rejection of part of the siliceous gangue, little concentration was obtained by this method of treatment.

Study of the data obtained from the screen analysis and preliminary leaching, smelting, and sponge-iron tests indicates that phosphorus cannot be satisfactorily rejected from the ore by these

TABLE 7. - Results laboratory sponge-iron tests

Grind	Reduced ore: Assay, percent Fe	Reduced ore: Assay, percent P	Reduced ore: Dist. percent Fe	Reduced ore: Dist. percent P	Magnetic: Assay, percent Fe	Magnetic: Assay, percent P	Magnetic: Dist. percent Fe	Magnetic: Dist. percent P
-8-mesh	60.2	0.83	100	100	61.7	0.84	90.8	89.8
-28-mesh	60.2	.76	100	100	62.2	.76	84.4	82.6
-100-mesh	60.5	.76	100	100	61.8	.82	47.2	50.0
-200-mesh	60.3	.78	100	100	61.5	.80	60.9	61.0

Grind	Middlings: Assay, percent Fe	Middlings: Assay, percent P	Middlings: Dist. percent Fe	Middlings: Dist. percent P	Nonmagnetic: Assay, percent Fe	Nonmagnetic: Assay, percent P	Nonmagnetic: Dist. percent Fe	Nonmagnetic: Dist. percent P
-8-mesh	55.1	0.72	8.1	7.7	29.4	0.76	1.1	2.5
-28-mesh	57.9	.78	13.7	15.0	27.8	.44	1.9	2.4
-100-mesh	60.7	.70	37.4	34.3	56.2	.72	15.4	15.7
-200-mesh	59.8	.78	29.2	29.2	55.4	.71	9.9	9.8

Note: The reduced ore rapidly reoxidized, even at room temperature; therefore, it was necessary to discharge it from the reducing atmosphere into water.

methods. By roasting the ore and leaching with a dilute solution of sulfuric acid, two-thirds of the phosphorus was taken into solution. However, the residue still contained an objectionable amount of phosphorus, and this treatment would be costly, as it involves roasting at high temperature to change the physical nature of the ore and the use of much sulfuric acid.

REDUCTION OF THE ORE

Two general processes might be applied to iron ores from this field — (1) reduction to sponge iron and (2) reduction to pig iron.

The general procedure in sponge-iron production is to heat the ore under reducing conditions, such as an atmosphere composed largely of carbon monoxide, to about 1,000° C. Under these conditions, iron oxide is reduced to metallic iron. The reduced material is then cooled and may be treated by magnetic separation to remove gangue and particles of unreduced iron oxide.

Scappoose iron ore could be reduced to pig iron by either blast-furnace or by electric-furnace treatment. However, the conventional 500- to 1,000-ton blast furnace is necessarily limited to ore bodies considerably larger than the Scappoose deposits. As electric furnaces are individual units, each of 50 and 100 tons of pig iron per day (6,000 and 12,000 kv.-a., respectively) capacity, these would be suitable for relatively small deposits, provided such operations were economically justified. Electric power for such a plant at Scappoose would be furnished from the Bonneville-Grand Coulee system.

The manufacture of steel from pig iron would require open-hearth furnaces, which would be either oil- or gas-fired, or electric steel furnaces. The combination of pig-iron smelting by electric power and conversion to steel therefrom by electric power does not exist in the United States, although electric-furnace conversion of pig iron and scrap to electric steel is common. Low power costs in the Pacific Northwest may favor consideration of an all-electric operation.

COST OF OPERATION

The cost of operation will vary with the type of mining — opencut or underground. Besides the cost of labor, supplies, and power, taxes, overhead, and development also must be included. These costs, as given in table 8, are estimates based upon general operation data[5] but revised somewhat for the Scappoose ores because of local and mining conditions.

TABLE 8. - Total mining costs per long ton of ore

	Underground	Opencut
Mining	$2.32	$0.84
Transportation	.18	.72
Development	.20	--
Taxes	.50	.50
Overhead	.30	.20
Total	3.50	2.26
Total cost per unit, natural	.09	.06

The estimated production costs per long ton of pig iron in a plant having a capacity of 50 long tons of pig iron per day are given in table 9.

5 Baxter, Charles H., and Parks, Roland D., Mine Examination and Valuation: Michigan College of Mining and Technology, Houghton, Mich., 2d ed., 1939, p. 304.

TABLE 9

	With coke ovens	Without coke ovens
1. Drying and sintering 2.5 tons ore	$1.50	$1.50
2. Coke, 900 pounds.	3.15	5.40
3. Electrodes, 20 lb. at $0.05 per lb. . . .	1.00	1.00
4. Flux, 600 lb. at $3.50 per ton.	1.05	1.05
5. Power, 2,500 kw.-hr. at 2 mills	5.00	5.00
6. Labor, 4 man hours.	3.00 to 5.00	3.00 to 5.00
7. Furnace repairs	.50	.50
8. Overhead, including taxes, amortization, insurance, and interest.	3.50	3.50
9. Total smelting cost	18.70 to 20.70	20.95 to 22.95
10. Cost of mining 2.5 tons ore from opencuts. .	5.65	5.65
11. Total cost of pig iron from opencut mining .	24.35 to 26.35	26.60 to 28.60
12. Cost of mining 2.5 tons ore, underground .	8.75	8.75
13. Total cost of pig iron from underground mining	27.45 to 29.45	29.70 to 31.70

If coke ovens are installed at the plant, the cost of smelting is estimated to be $20.70, as compared to $22.95 per ton without these facilities. However, these costs are estimated to be $2 per ton higher than during normal times when labor costs are less.

The total cost of pig iron, including mining, is estimated at a minimum of $24.35 and a maximum of $31.70 per long ton. The factors having an important bearing upon the costs are: (1) War or peacetime conditions, (2) whether coke is produced at the plant or purchased from local markets, and (3) whether the ore is obtained from opencut or underground mines.

Quotations on pig iron ranged from about $24 in 1922 to $23.60 per ton in 1942. The cost of pig iron from Provo, Utah, delivered at Portland is $26.95 per ton, of which $4.95 is freight. The estimated costs in table 9, item 11, show that, with coke ovens installed as an adjunct to the furnace plant and with the extraction of ore from opencut mines, they favor somewhat the production of pig iron from Scappoose ore. It is possible, too, that under certain favorable conditions, these costs may be reduced as much as $2 to $3 per ton of pig iron. This would make the production of pig iron from opencut mines more feasible and would also favorably affect the underground operations. Such conditions would be exceptionally competent management, better mining conditions than anticipated, the occurrence of much coarse material in the dried ore (which would not require sintering), the possible overestimation of capital cost (which would reduce the overhead costs), and a well-designed furnace and pipe-casting plant (which could make the most efficient use of labor).

Owing to the high phosphorus content of the Scappoose ore, the pig iron would be inferior in quality to Provo pig iron. It would also be below market standards, unless processes were applied to remove the phosphorus. Such treatment would increase the cost of the pig iron. As this cost may be too high to compete with that of pig iron from other sources, a suitable outlet for Scappoose pig iron may be in the direct manufacture of cast-iron pipe.

The cost of a 50-ton-per-day electric pig-iron furnace plant using the Norwegian Spigerverk or Tysland-Hole furnace was estimated to be $625,000, complete with building, sintering plant, transformers, and all necessary auxiliary furnace equipment. This cost reflected present high costs of construction. A 100-ton furnace or two 50-ton furnaces could be installed with relatively small increase in capital cost.

The cost of underground development and equipment to mine 125 tons of ore per day can only be estimated. It is probable that $200,000 would be adequate for these purposes. At the production rate of 50 tons of pig iron per day, the indicated ore reserves that can be mined by opencuts would last about 17 to 20 years, and the estimated total recoverable ore reserves from both opencut and underground mines would last for about 70 years. Little development would be required for opencut operation. It is estimated that the equipment would cost $75,000. In considering underground operations, the capital cost, including the sintering and furnace plants, is estimated at $825,000. A similar operation using opencut mining is estimated at $700,000. It is possible that a cast-iron pipe plant and coke oven of 50-tons-per-day capacity would increase the total capital cost to about $1,500,000.

CONCLUSIONS

The Bureau of Mines concludes that:

1. The Scappoose iron-ore deposits contain an estimated 4,049,000 long tons of iron ore that will average about 39.1 percent iron, 19.7 percent moisture, 0.037 percent sulfur, 0.58 percent phosphorus, 0.47 percent manganese, 4.30 percent silica, and 3.4 percent alumina.

2. The deposits are of two types. One has much overburden and must be mined by underground methods, whereas the other has little overburden and can be mined by opencut methods. The following table gives the tonnage in each class as well as the amounts estimated to be recoverable:

	Indicated ore, long tons	
	Reserves	Recoverable
Underground mining.	3,102,500	2,140,000
Opencut mining.	947,000	764,950
	4,049,500	2,904,950

3. If 2,904,950 tons of iron ore were mined, about 1,160,000 tons of pig iron containing 1 to 2 percent phosphorus could be made therefrom. It is possible that the phosphorus content could be reduced by additional treatment, should this be necessary or desirable.

4. Perhaps Scappoose pig iron could be used to best advantage in the direct manufacture of cast-iron pipe. However, conclusive evidence as to the success of such an operation is lacking. A thorough investigation of market demand, price of cast-iron pipe, and cost of production should be made by property owners or other interested persons. The possibilities of producing other iron and steel products when scrap iron is plentiful should be studied also.

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