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THE MINERAL RESOURCES OF OREGON

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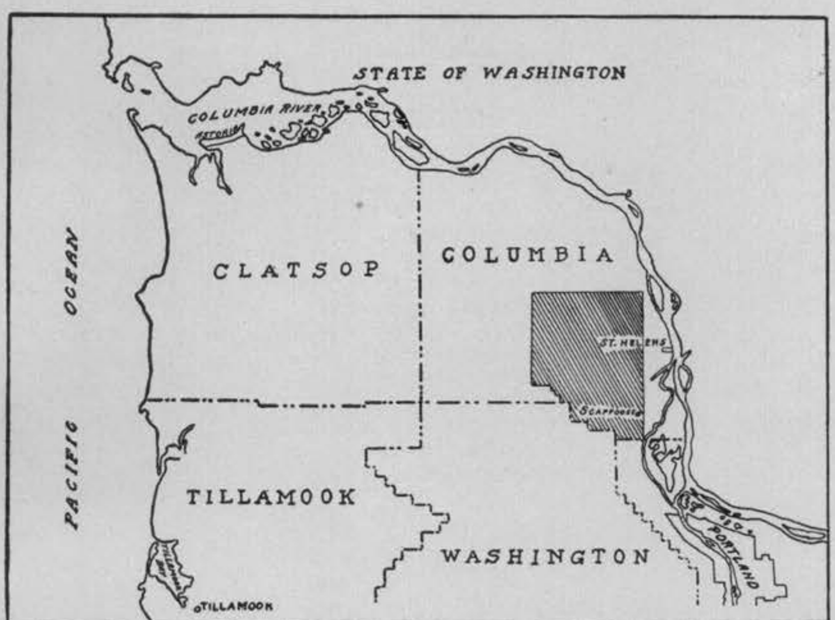

Outline map showing location of Columbia County iron ore deposits

REPORT ON

The Limonite Iron Ores of Columbia County, Oregon

Forty-four Pages Seven Illustrations

STATE OF OREGON

WALTER M. PIERCE, Governor

BUREAU OF MINES AND GEOLOGY

HENRY M. PARKS, Director

417 OREGON BUILDING, PORTLAND, OREGON

IRA A. WILLIAMS, Geologist

G. E. STOWELL, Mining Engineer

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INTRODUCTORY

The establishment of an iron industry on the Columbia River harbor would be an event of major importance in the commercial and industrial development of the entire state of Oregon. Since early in 1920 there has been considerable activity in the prospecting of iron ores in Columbia county contiguous to the Columbia river, within approximately 20 miles from Portland.

An appropriation was made by the 1921 legislature to determine the occurrence and magnitude of the iron ore resources of Columbia county, and to investigate the conditions which would control in the manufacture of iron in this vicinity. The present report sets forth the results of this investigation and is intended to be both a guide to future development work in the Coast range occurrences of iron ore, and a digest of the fundamental factors that determine the commercial feasibility of manufacturing iron near Portland.

The origin, character, and extent of the ore deposits are discussed. The economic features of iron production, the technical and commercial elements of charcoal manufacture, and the manufacture of sponge iron are authoritatively treated in three separate chapters. A map is presented which shows the topography of the principal area where the ore is found, the distribution of the rocks with which it is associated and the location of the chief ore occurrences yet discovered. This map and the accompanying discussion furnish the basic facts on which intelligent prospecting and exploitation of the ores of Columbia county will depend.

The geologic field work for this report was done by Ira A. Williams and G. E. Stowell of the Bureau staff, and the writer. The topography was mapped by D. C. Livingston and J. H. McFarland, who were in the temporary employ of the Bureau. Acknowledgment is hereby made for the constant co-operation of the officials of the different timber companies having holdings in the area. Thanks are due also to many persons for information particularly in connection with the development work on the several properties where the ore has been opened up.

HENRY M. PARKS, Director.

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THE MINERAL RESOURCES OF OREGON

A Periodical Devoted to the Development of All Her Minerals

PUBLISHED AT PORTLAND BY

THE OREGON BUREAU OF MINES AND GEOLOGY

HENRY M. PARKS, Director

THE LIMONITE IRON ORES OF COLUMBIA COUNTY, OREGON

By IRA A. WILLIAMS and HENRY M. PARKS

SUMMARY

Some of the salient facts brought out in this report are given in the following paragraphs—

(a) Important conditions favorable to the establishment of an iron industry on the Columbia river:

1. The existence of good limonite iron ores which can be mined and transported to the Columbia river harbor at a low cost.

2. Favorable conditions of transportation for all materials and products used in the industry.

3. An established Pacific Coast market for sufficient quantity of foundry iron to warrant an initial plant.

4. A price for the product which will be protected for an indefinite time in the future by the freight costs on iron from eastern producers.

(b) Factors of less certainty:

1. The fuel, which would be coke from Washington, British Columbia, Alaska, Australia or other foreign ports; or soft wood charcoal.

2. Limestone for flux, which would probably come with least cost from the North Puget Sound country by barge.

THE IRON ORES

A study of the geologic map accompanying this report and of the occurrence of the limonite ores as set forth in the following pages will show that these ores originated from basaltic rocks by weathering, and that they accumulated as bog iron deposits distributed intermittently over an earlier land surface than the present topography represents.

The prospecting of these ores to date is scattered, and in only a few cases has been prosecuted in any systematic way. The total quantity of ore developed is not large, amounting to approximately a million and a half tons, with an indicated additional tonnage of, in all probability, two to three times that amount at points well distributed over about four townships. The important feature, however, is that the present limited development, when viewed in the light of the occurrence of the ores, makes it highly probable that if a systematic plan of development were carried on over unexplored lands where iron indications are known to exist, the present known tonnage would be multiplied many fold, with the likelihood of a reserve which would be ample for the basis of a large iron industry.

The quality of the Columbia county ores is better than is usual for limonite ores the world over. The average iron content of Lake Superior hematite is now below 50 per cent. The ores in the great iron fields of Eastern France, Alsace and Luxemburg run from 31 to 40 per cent. The domestic ores smelted in the British Isles for the past five years have carried only 20 per cent iron. The limonite ores of the Birmingham, Alabama, district run only 35 per cent. Columbia county ores run better than 40 per cent iron (natural) and thus compare very favorably with those in other parts of the world which are now being used commercially.

MARKETS

Many opinions have been expressed recently concerning the market for iron on the Pacific Coast. The investigations of this question show that the demand for foundry iron varies from year to year, but that there is without question market for more than a thousand tons per day. This is a greater output than can probably be manufactured for a number of years to come.

FUEL

A supply of suitable fuel is probably the most uncertain of the factors entering into the manufacture of pig iron. The state of Washington at the north has coals in the Carbonado and Wilkinson districts from which a fair grade of coke has been made. The ash in Washington coke is a little higher than would be desired for iron smelting. Fairly good coke can also be had from northeastern British Columbia, but the freight would probably make the cost too high for consideration.

Beehive coke, similar in quality to the Washington product, is available on tidewater at Comox, in western British Columbia.

Alaska has some excellent coking coals and it is anticipated that the plans of the Alaska Coke and Coal Co. (a corporation financed by Portland capital), when fully matured, will make available coals of high quality which may have a very important bearing upon the manufacture of iron in this vicinity. Australian coke of good quality is also available. On account of water transportation, it can be delivered on the Pacific Coast in cargo lots at a cost that will make it a factor to be considered.

It is possible to manufacture pig iron with soft wood charcoal; but there is some uncertainty as to what the actual cost of this fuel would be on account of the lack of information as to the amount and value of the by-products produced from fir wood. There seems little doubt that charcoal would cost more than coke from the sources mentioned.

FLUX

Oregon has large deposits of limestone, both in the eastern part of the state and in the southern. It appears probable, however, that limestone can be had from the North Puget Sound country, delivered in the Columbia River harbor by barge, at a less cost than that of the Oregon product.

Taking all factors into consideration, it is a reasonable conclusion that there are sufficient ores of fair quality contiguous to the Columbia river and that the economic factors are sufficiently favorable to warrant the establishment of an iron industry at some convenient point on the Columbia river.

LOCATION OF THE IRON-BEARING AREA

Columbia county lies next to the Columbia river, which flows between Oregon and Washington, and is separated from the Pacific ocean by Clatsop county, which is in the northwest corner of the state of Oregon. The area under consideration, which is covered by the acompanying map and in which the main iron ore occurrences are found, occupies its southeast portion and is bounded in part at the south by Multnomah and Washington counties. It is included essentially within townships 3, 4 and 5 north from Willamette base line in ranges 2 and 3 west of Willamette meridian. The Columbia river is at its eastern edge. It is paralleled by the Columbia river highway and the Astoria branch of the Seattle, Portland and Spokane railroad, which connects with all transcontinental and coastwise lines at Portland.

TOPOGRAPHY

This portion of Columbia county is deeply gashed by a number of streams that flow to the eastward into the Columbia river and by the headwaters of others that take a southwesterly course and are tributaries of the Nehalem river, a major stream that cuts across the Coast range of mountains to the southwest directly to the Pacific. The divide between the two drainages is near the west side of the area, its highest points reaching altitudes in a few places of 2000 feet and over above the sea.

The north and south forks of Scappoose creek and Milton, Merill and Tide creeks with their tributaries drain eastward to the Columbia. Clatskanie river flows northwestward towards the Columbia and drains a section in the north part of the tract. Leading to the westward are the east fork of the Nehalem river with headwater branches, and Cedar and Oak Ranch creeks, which cross the boundary line near the northwest corner of the map.

All streams have steep grades and have cut sharp deep canyons into the rocks that underlie the region. Those that come down into the Columbia are traversed by logging railroads and, in general, by wagon roads that lead to the various camps and settlements back from the river. An east-west improved county road goes up Milton creek through Yankton and Trenholm and passing over the divide joins the main highway along the Nehalem river at Turrish, one mile and a half outside of the area being considered.

Practically the east three-fourths of this area has been logged off and clearing and occupancy of the land by settlers are in progress. The entire region was formerly heavily forested and logging operations are now under way at various points progressing towards and mostly in the western part of the area. The region is thus fairly open and accessible to examination and prospecting.

As already stated the relief of this part of Columbia county is marked. The country rises from the Columbia river, which is here less than 50 feet above tide, to a maximum altitude of about 2000 feet in less than six miles to the westward. Careful study of the land surface reveals the presence of portions of a series of terraces as one rises from the river. These appear as broad farming flats low down and as mere fragments of former flats against the horizon at many places on the divides between stream canyons. Sometimes they are a series of well-marked steps or even-topped benches, which appear most conspicuously near the summit of the divide in the south central part of the area. This summit itself seems in part the remains of a similar old even land surface with here and there along it some hills that rise above the former plain.

These benches represent portions of former land surfaces that were produced by erosion when the country stood at lower levels than now. That there are a number of them one above another indicates the different positions with reference to sea level that were successively occupied by the region during its elevation to its present position. The conception that one should have of this region is therefore that its present topography has been developed by a process of elevation, interrupted by repeated long intervals of quiet, during which the streams of today, the Columbia included, aided by all weathering influences, have been actively carving deep canyons into it. Any study of its surface features now, of the rocks that underlie it, or of the occurrence and character of such economic deposits as they may contain, can be intelligently made only with a full knowledge of these conditions of the past constantly in mind.

GEOLOGY OF THE IRON ORE

The rocks in this part of Columbia county are mainly sandstone, shales, and basaltic lavas, all of Tertiary age. Some of the lower lying lands near the Columbia are covered by alluvium, which extends varying distances up the main streams already named. The areas occupied by these three groups of rocks are sufficiently distinctive that they have been outlined, in color, on the accompanying map.

This classification of the rocks of the region will be more serviceable than a purely chronologic one in the present paper because of the proved general association of the iron ores with the basaltic lavas only. While the whole area is underlain with sedimentary and eruptive Tertiary rocks, the purpose of this report is not such as to require the working out in detail and recording of minor structural features and relationships. Columbia county is included within the area covered by the Coast range of mountains. This range has been formed by a broad upward arch of the Tertiary formations whose axis runs in a general north-south direction. If a cross section of the range were made it would be seen that this wide spreading geanticline, as it is called, is composed of a number of super-imposed lesser folds, most of which show a parallelism to the general course of the range.

In the study of a specific or restricted locality, however, it is not always possible to make out such a relationship in structure to the main Coast Range uplift. Its axis doubtless changes direction materially in places, more or less of faulting has in all probability taken place in connection with the growth of the range, and the intrusion of igneous rocks has disturbed the normal position of the sedimentary rocks to a large degree.

Within the limits of the map shown many observations of dip and strike have been made. Inclinations are prevailingly low, from a few up to 10 or 15 degrees, and although the basaltic lavas conform in general with the underlying sediments the small departures from the horizontal are of no practical importance. Though this iron-bearing area lies at the eastward side of the summit of the main uplift, the most evident deformation appears to be a series of low folds with axes running in a general east-westerly direction.

Reference to the map and cross sections brings out very clearly the fact that the basaltic lava overlies the shales and sandstones. Wherever it occurs it is the top or surface formation and much of the iron-stained "shot" soils of the region is due to its alteration. Parts of the area are thus lava-covered which vary in altitude from almost the highest to the lowest. It is apparent that for most of the region the basalt-covered portions found today are but remnants of what was a much more general lava blanket upon the surface of the land. Elevation and erosion have effected the removal of intervening portions, the latter process having continued deep down into the underlying sandstones and shales.

While the lava cover shares in general the attitude of the underlying beds, in the field one is impressed at once with the fact that when these lavas came they must have flowed across an already uneven old land surface filling in all depressions and submerging as well most of its higher portions. We thus find at present an irregular contact of the lava upon the sedimentary rocks, an unconformity, it is called. Columbia county was at a much lower level than now when these lava flows came out upon it.

The sedimentary rocks that occur here are mostly such as have been deposited in deep water, probably in the depths of the ocean. Many marine fossils are to be found in the sandstones and shales, which tell of the age in which they were formed. On the basis of the fossil forms that have been identified, there probably exists within the boundaries of our quadrangle, rocks belonging to the Eocene, Oligocene and Miocene periods of the Tertiary. Bodies of partially cemented gravels occur in a few places which may prove to be of more recent age, while the gravel and silt-covered terraces along the Columbia and floodplain deposits range from Pleistocene to modern in the time of their formation. The earlier marine Tertiary beds, as indicated on the cross-section, occur mainly nearer to the Columbia, while the later Oligocene and Miocene appear successively above the Eocene towards the western side of the area. The basalts overlie all and are also probably Tertiary in age.

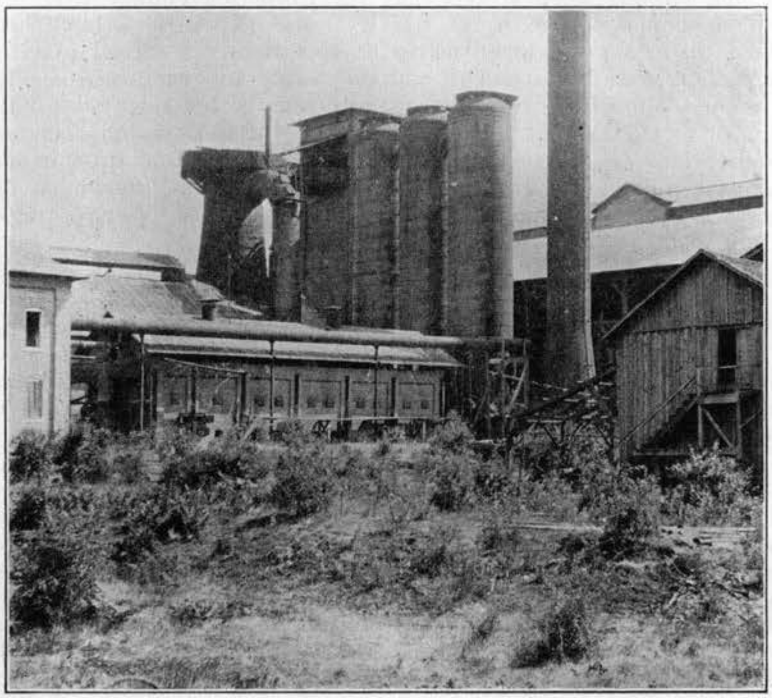
OCCURRENCE OF THE IRON ORES

Probably one-half or more of the area mapped is covered by the basaltic lava. It is the topmost formation and has thus suffered greatly by weathering and erosion. As a rule the principal outcrops of basalt are found well up towards the top and along the summits of ridges and not infrequently shales or sandstones, or both, appear below. It is upon the steeper slopes and along sharp stream gulches that the first signs of iron ore have been found. These consist usually of lumps of the hard variety of ore and less frequently outcrops of the soft brown type.

The basalts are commonly much altered by weathering. Sometimes the original rock has been changed into a deeply iron-stained soil and again into a clay residuum that is light yellow or whitish in color. The typical basalt soil is of reddish color and filled with shot-like concretions of limonite. This fact has given rise to a current use of the term "shot" soil. Some of these soils contain a fairly high percentage of iron. On the other hand, the light-colored residual clay, which occurs mostly some distance beneath the surface, is often nearly free from iron oxide. Many fresh basalts contain 10 to 12 per cent or more of iron oxide. A higher amount than this in the resulting soil means that in breaking down a process of iron concentration has gone on, while a partial or complete absence of iron in the residual clay on the other hand indicates as certainly that a removal or loss of this element has accompanied disintegration of the rock.

It is to be drawn from the foregoing that, first, the original basalt contains, among igneous rocks, a large percentage of iron, and secondly, that in weathering, the iron is released and may be taken away entirely or deposited in or near to the position of the original rock as we see in the iron-charged basaltic soil. The decay of the rock is brought about in large part through the agency of water which enters and gradually moves through it, producing chemical changes and dissolving such soluble substances as are formed. The iron of the unweathered rock exists largely in silicate combination.

When it is freed by weathering much of it becomes soluble and therefore subject to being dissolved and carried away. The iron compounds formed will remain in solution until somewhere in the course of its movement the circulating water meets conditions in which the iron is precipitated. The iron-bearing solution may seep out along hill slopes and give rise to iron springs where much of its iron is deposited. Capillarity may carry it to the surface over large areas and by evaporation or chemical reactions the soils may become saturated with hydrous iron oxide as in the red soils. Again, the waters which have gained their iron content from an area of altering basaltic rocks may not meet conditions by which they will be relieved



Blast furnace at former iron smelting plant of Oregon Iron and Steel Company, Oswego

of this iron until they have reached a swamp or shallow lake where beds of bog ore are formed.

In the Columbia county iron district the heavy bodies of basalt evidently consist of what remains of many separate lava flows. The source of these flows can only be conjectured, but it is entirely probable that they came up from the earth's interior through cracks or crevices in many places. It is not unlikely that some of these points of issuance are within the quadrangle under consideration. Neither is it certain how long a period of time is represented by the flows.

We know that the earliest of them came out upon an uneven land surface carved in other types of rocks. In many places outside of Columbia county abundant evidence is found that periods of time of considerable length elapsed between flows. During these intervals erosion and weathering, soil formation and plant growth proceeded much as at present. Each flow overwhelmed and covered whatever of sediment, soil and plant accumulation may have taken place upon the preceding one. When, then, we examine these flows as they are exposed today, we are studying a cross section, as it were, of the record of the happenings of those early times in which the repeated lava flows first spread out upon the land.

It has already been stated that the Columbia county iron ores occur in association with the basalt flows. These ores have been opened up in several localities to be specifically referred to later, where their exact relationship can be seen. In every instance the ore is enclosed within the lava, usually plainly between two of the flows, or at the base of the lava and upon the old erosional surface of sedimentary rocks below. So constant is this association it may be stated confidently that only in the basalt areas, shown on the map in red, is there any promise whatever to the prospector of finding iron ore.

ORIGIN OF THE IRON ORES

We have already seen that basalt is a lava sufficiently rich in iron-bearing minerals to furnish, by weathering, the iron for deposits of iron ore. Among those who have studied this region two main methods have been proposed to account for the beds of ore as they are found. By some they are believed to have been formed through a process of residual concentration in the position and during the weathering and alteration of the original basalt. The second method is one of accumulation in swampy places or shallow lakes as so-called bog iron ore. A knowledge of the exact mode of origin is of vital importance in connection with any proposed development or systematic prospecting of the iron deposits.

One may think of accumulation by replacement of the original rock as taking place either under surface conditions or at depth. In the first case the process would in general be that by which the ferruginous soils are formed, erosion being absent or so sluggish that layers of some thickness could form. Such old soils would then be covered by later flows in order that we may find them in their present positions. A second phase of residual accumulation is illustrated by the growth of concretionary masses within the earth away from surface influences. Concretions are large or small, often round or oval in shape, or may be bands or beds or ledges extending an indefinite distance along certain zones or horizons. The concretionary substance itself may have originated close by or at a distance. In order that sufficient rise in iron content to become an iron ore could take place in a weathering basalt a correspondingly large amount of the other constituents of the rock must be removed.

In breaking down under ordinary conditions of weathering the principal portion of the basaltic residue is clay. This clay forms through the hydration of aluminum silicates that were in the rock, and is the least soluble and most apt to remain of all the products of decay. Residual deposits of iron ore would therefore be expected to contain as a rule considerable amounts of clayey matter. The known commercial deposits of residual iron ores are all contaminated with more or less of clayey matter, though none have originated from rocks with as high an original content of silica and alumina from which the clay comes as the basaltic lavas contain. The percentage of insoluble impurities in the many samples of Columbia county ore that have been analyzed runs low as compared with the quantity that would remain in the normal weathering of the lava.

The second method of origin mentioned above, that of accumulation in shallow lakes or swamps as "bog" ore may be briefly treated. Bog ores form by the precipitation as hydrated iron oxide, limonite, and often some carbonate, of the iron brought in solution in the waters coming from nearby areas of weathering iron-bearing rocks. Basalt is rich in minerals that contain iron and this is dissolved, mainly due to the presence of carbon dioxide from the air, sulphuric acid when it is present, and decomposing organisms and the organic acids derived from decomposing vegetable matter. Precipitation of iron takes place when the carbon dioxide escapes, or when the ferrous sulphate comes in contact with the air. "Iron bacteria" are thought to be of importance in releasing the iron from its combination with the acids of organic decay.

The result of the operation of these processes is to produce deposits of impure iron ore, sometimes several feet in thickness and in a few places in the world of commercial quality. The common impurities which they contain are naturally such clayey matter and sand as would be brought in by streams at the same time, and the remains of plants, leaves, stems, the wood of trees, that either float or grow in or about the borders of the lake or swamp. Bog ores are forming today in many places where their nature and the process of deposition may be observed.

We may now examine the Columbia county ores in the light of our knowledge of bog iron ores and those of the residual type and their methods of accumulation. First of all, they are, wherever seen, what would be called "soft" ore, with more or less continuous bands of "hard" ore running through practically every deposit. The bands of hard ore are from one inch to 6 or 8 inches in thickness, and as a rule are higher in iron than the soft variety. The soft ore varies from pulverulent brown iron rust to a deep brownish red of granular texture. The ores occur in beds from three to twenty feet thick. Where prospecting has been carried on, these beds are found to underlie areas of considerable extent. Each bed rests upon altered basalt below or the bleached or vari-colored residual clay from the alteration of this rock. Altered basalt also covers the iron ore beds, and the ore, thus, so far as can be seen, is enclosed between lava flows and partakes of the same attitude or inclination as do the accompanying lava layers.

Between the ore and the overlying basalt in many of the cuts that have been made is a layer of fragmental material resembling a tuff-breccia or ashy clay. The latter is the more common and runs six to eight inches thick in places. It shows what is apparently the bedding planes that are characteristic of sediments deposited in quiet water, and its contact with both basalt above and ore below is customarily sharply marked. The ashy clay sometimes grades upwards into the iron-stained volcanic tuff which contains angular pieces of altered lava scattered promiscuously through it and lacks any evidence of having formed under water.

Within the ore at one well-developed series of prospect openings, and particularly toward the base of the bed, quantities of petrified wood are found. Pieces as large as logs and branches occur plentifully, in such position as to suggest quiet settlement upon a mass of accumulating iron ore. At some later time and long prior to the present the organic structure of the wood was largely replaced by the deposition of silica from mineralized moving underground waters.

We may thus most satisfactorily picture the formation of the iron ores that are now being discovered and opened up in Columbia county as having taken place in ponds, along sluggish water courses and in swamps or lakes, that existed upon a basalt land surface of long ago. It was a land surface of low relief and poor drainage, yet one so exposed to the action of the agents of rock decay that an abundance of iron compounds was contributed by the weathering basalt to the streams that discharged their waters into those places of accumulation. Here their iron content was precipitated as "bog" ore, and floating trees and other vegetal remains and whatever of soil particles, silt, clay or sand likewise settled into these depressions in the land.

Then came a day when ore deposition ceased. Perhaps not distant volcanic eruption contributed to incoming streams an unusually large amount of ash and then larger pieces to mix with the clays so that in places the iron ore was blanketed above by a seal of impervious sediments or covered by a sheet of volcanic tuff that filled to elimination the water body in which the bed of ore had grown. This series of events, whose progress doubtless extended through many thousands of years, was next succeeded by the coming of a deluge of lava, portions of which we now see above the iron ore, that must have swept across we know not how great a stretch of country. This flow, like that on the surface of which the iron ore was deposited, extinguished all life and produced many changes of topography. Following it came others, time and again repeated and with varying intervals between, which built the great thickness of the basaltic capping that today overlies the sedimentary rocks in parts of Columbia county.

We must regard the time of deposition of these ores as of long duration. Lava flow succeeded lava flow but between several of them conditions were favorable and the time interval long enough for vegetation to develop, perhaps forests to flourish, and iron ores to accumulate. And this opens to us at once the plausible and correct inference that the various ore bodies discovered were not necessarily deposited at the same time or in parts of the same body of water, but as likely represent different swamps or lake bottoms and even different time periods between lava flows. It should be kept in mind, however, that the ore is always associated with the lava and will not be found in the earlier sandstones and shales.

DEVELOPED ORE AND PROSPECTS

Somewhat outside of the particular area mapped for this report is the only deposit of iron ore from which there has been commercial production in Oregon. This is a deposit of limonite near the town of Oswego, about 8 miles south of Portland in Clackamas county. As described by J. S. Diller in Part I of the 17th Annual Report of the United States Geological Survey, the outcrop of the bed shows 2 to 8 feet of ore having a dip to the west of north varying from 8 to 30 degrees in several hundred feet of workings. It lies between two layers of basaltic lava.

As the only body of iron ore in Oregon that has been thoroughly opened up, the Oswego deposit is of particular interest since its character and relationship to the enclosing rocks are identical to those of the most extensive occurrences in Columbia county. The evidence of its having accumulated as a bog deposit seems conclusive and the facts on which this evidence is based are the same as observed in connection with the Columbia county ores.

The first and only iron yet produced in Oregon was made by the Oregon Iron Company and its successors at Oswego. The ore used came from the bed of limonite already referred to as occurring between sheets of basalt two and one-half miles west of the town of Oswego. The plant began producing in 1867 and was finally closed in 1894. Pig iron and cast iron pipe were made. Charcoal made at the plant was the fuel used. Records show that the plant was fully equipped and up-to-date at the time of its construction. Increased costs of mining and variations in the grade of the ore determined the final abandonment of this effort.

The Oswego deposit is known to be one by one-half mile in extent, its thickness, as shown in the workings, ranging from 2 to 20 feet. Chemical analyses of the ore given by Mr. J. S. Diller in the 17th Annual Report of the United States Geological Survey, Part I, page 508, are as follows:

	Per cent
Metallic iron	30.00 to 40.00
Silica	7.00 to 15.00
Magnesia	2.00 to 3.00
Manganese	4.00 to 8.00
Lime	2.00 to 4.00
Phosphorus	0.37 to 0.67
Sulphur	0.3 to 1.00

In physical character the ore varies from soft and friable to hard and flinty. The latter is apparently more highly siliceous in composition, although streaks of the harder variety were found to be richest in iron content.

A deposit of limonite known also many years ago was the Payne and Rafferty mine on the north fork of Scappoose creek within the area covered by the present map, and from which it is said a few hundred tons of ore were taken. The ore here lies between decomposed basalt flows and is otherwise similar to neighboring bodies of iron ore in Columbia county.

Again, outside of the present map, showings of limonite are found, associated with eruptive rocks, to the southwest in Washington county along and in the vicinity of the west fork of Dairy creek. None, however, has been worked, and it is not known how extensive deposits there may be in these regions contiguous to the area which the accompanying map covers in some detail.

IRONCREST PROPERTY

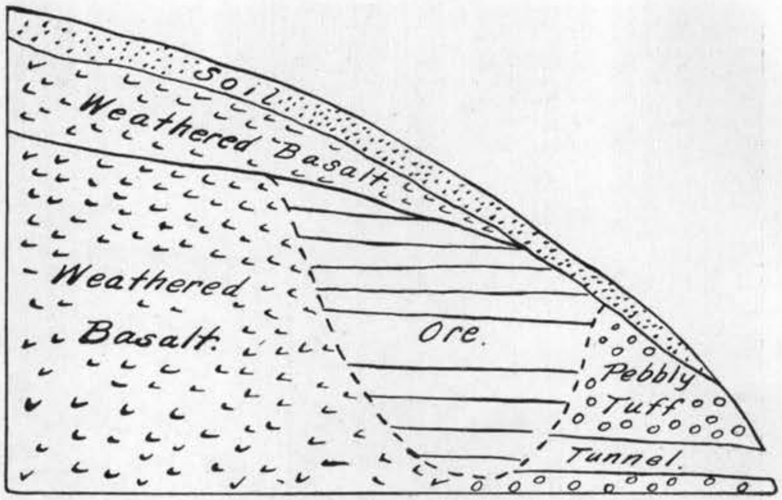
This group of claims is located in the south part of section 35, township 4 north, range 3 west, at an altitude of 2000 feet on the summit of the divide between the north fork and the south fork of Scappoose creek. A wagon road follows up the divide from the town of Scappoose to Pisgah Home, which is within about one mile of the edge of the property. It may be reached also by trail from the highway at Vernonia and other points within the drainage of the Nehalem river to the westward. The claims are held by Mr. H. E. Heppner, Mr. H. A. Heppner, and Mr. C. A. Finley, all of Portland.

Active prospecting was begun in this locality in 1918. The principal openings consist of a series of cuts and a number of tunnels in a distance of one-half mile along the north slope but barely below the top of the ridge in the southwest part of section 35. Some 30 drill holes have also been put down in a 40-acre strip along the adjoining saddle in the north part of the southeast quarter of this section. The holes were spaced about 200 feet apart and are said to have practically all reached ore through a shallow overburden of weathered basalt varying from two to twenty feet thick. The bed of iron ore shown in the holes is reported by Mr. Heppner to average 10 feet in thickness.

A number of interesting facts are displayed in the open cuts and tunnels which bear on the genesis of the Columbia county limonite ores. The face of ore shown in the openings ranges from 4 to 18½ feet and will probably average 10 feet. The ore is soft, yellow to brown in color, with irregular bands of the hard variety running through it. At the entrance to one of the tunnels, and in some of the more westerly of the series of open cuts, the bedrock on which the ore rests is a sticky gray clay containing occasional perfectly water-rounded gravel pebbles. The pebbles are large and small, light in color, siliceous, many of them undoubtedly vesicular rhyolite. The clay contains also numerous pieces of silicified wood and masses of opalitic cellular silica which is sometimes banded as if due to the imperfect replacement of a wood structure.

Open cut at Ironcrest. Fifteen feet of ore overlain by weathered basalt

This material, which now has the characteristics of a gravelly clay, appears to be in reality a much-weathered fragmental rock resembling a rhyolitic tuff which was obviously deposited in water and thus contains the wood and pebbles brought in by water action. One fossil mollusk was found in this bed but whether a fresh or salt water form is not determined for certain. In addition to appearing beneath the ore this clay-tuff is found in a number of the main openings to bear the relation to the ore indicated in the sketch. The beginning excavations were in the tuff, the boundary of the ore body when reached being an almost vertical wall.



Sketch showing position of the iron ore at Ironcrest

The sketch shows also the relationship of the ore to the basalt. The inner parts of the tunnels in every instance encountered a bleached yellow to white cellular residual basalt clay below the deepest portion of the ore. Within distances of 50 to 75 feet from the portal the base of the ore in all instances raised against a sloping face of weathered basalt until, where followed to that point, it pinched out at the contact with a later overlying lava flow.

While the depth of iron ore shown here in the open cuts and tunnels was thus promising at the start, the extent and therefore the actual quantity proven by this work were in an equal degree disappointing. The location of the ore, however, with reference to the immediately contiguous area to the northeastward where the drill holes already mentioned were put down, is such as to leave the inference quite clear that they are portions of the same bed of ore. Accepting the figures given for the thickness of ore found by drilling, there would appear to be outlined in the Ironcrest property as much as a million tons of ore.

The following tabulation shows the percentage of iron in 24 representative samples of ore taken by this Bureau from the cuts and tunnels at Ironcrest:

Sample	Iron (dry) Per cent
1	49.68
2	53.28
3	56.16
4	55.68
5	51.60
6	51.60
7	52.80
8	53.28
9	53.76
10	48.96
11	53.04
12	53.04
13	54.48
14	58.80
15	54.24
16	53.52
17	55.44
18	54.00
19	54.24
20	55.92
21	53.04
22	53.04
23	55.68
24	58.08

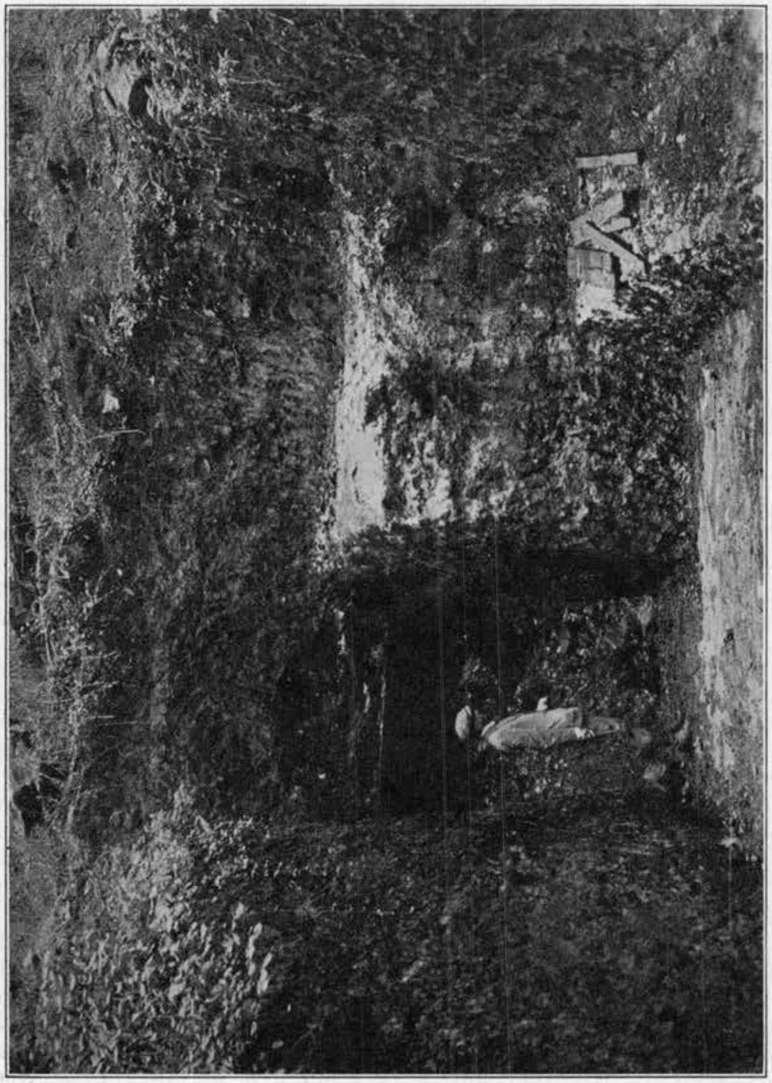
Phosphorus runs from 0.2 to 0.5 per cent. Sulphur, a trace.

A notable phase of this deposit is the quite general presence of a crust or casing of hard ore along the contact with the overlying basalt and especially the side or vertical contact with the pebbly tuff. This crust at the top has in places much the appearance of hematite, and while no analyses have been made to prove the fact, it is readily conceivable that the heat from the superincumbent lava, when it came, dehydrated to a slight depth the bed of bog ore over which it flowed and on which it finally came to rest, cooled and solidified. In the ore also is much of petrified wood. The wood occurs plentifully near the base of the ore body and in position resembles in all respects pieces that may have settled upon the ore as it was forming in the bottom of a pond, lake or waterway. Silicification of the wood by which its structure was preserved may have taken place through the action of hot silica-bearing solutions at the time the ore was covered by the later lava flow, or by infiltration of silica at some subsequent date during the weathering of the surrounding basalt.

The rather unusual shape of the main prospected body of Ironcrest ore as indicated in the drawing, is such as to suggest the filling with bog ore of a former channel or water course that here paralleled for a distance the unconformable contact of basaltic lava and a gravelly sedimentary rock. It may be thought of perhaps as a portion of the winding channel of a sluggish stream that flowed into the lake a small patch of whose bottom is now outlined by the bed of iron ore shown by the drill holes to exist along the ridge immediately contiguous to the northeastward.

OREGON CHARCOAL IRON COMPANY

The property of this company is about two miles northwest of the town of Scappoose on a low dividing ridge between the head of Apple valley and north Scappoose creek. It lies entirely in section



Open cut on property of Oregon Charcoal Iron Company. Seven to eight feet of limonite ore overlain and underlain by weathered basalt

3 of township 3 north, range 2 west of Willamette meridian and consists of 380 acres. The land is in part logged off and ranges in altitude from 300 to 650 feet above sea level.

The ore has been prospected by a series of open cuts and tunnels in the hillside and by drilling over a portion of the holding. By these means the presence of the ore has been proved to date beneath at least 80 acres. It occurs as a continuous bed which can be seen in the prospect openings to be between layers of altered basalt. A plotting of the position of the outcrops which range from 525 to 600 feet in altitude, and the drill logs, indicates that the bed of ore has a uniform inclination of a few degrees to the northeastward. This is apparently in conformity with the attitude of the basalt flows with which it is associated. The maximum capping of lava over the ore in that part of the property that has been drilled is not more than 200 feet. The overburden becomes heavier to the westward in the part of the property not yet prospected.

The thickness of the ore bed varies from 4½ to 13 feet and will average 7 feet. The ore is the soft and granular variety with streaks or bands of hard ore chiefly near the top of the bed. The basalt below is usually weathered to a bleached plastic clay of light or characteristic brilliant or variegated color. In some places altered cellular basalt rests directly on the ore. In many exposures, however, there is a layer from a few inches to a foot thick of micaceous stratified material resembling sandstone but composed largely of angular tuffaceous fragments some sufficiently large to give the bed the appearance of a breccia. The stratification is such as to indicate its deposition in water under conditions where little of sorting action was possible. Doubtful imprints of plant leaves and stems appear in this bed, and dendrites and at intervals irregular harder bandings that run high in manganese dioxide.

Analyses furnished by the company show the following iron content in clean samples taken from cuts and tunnels in the ore:

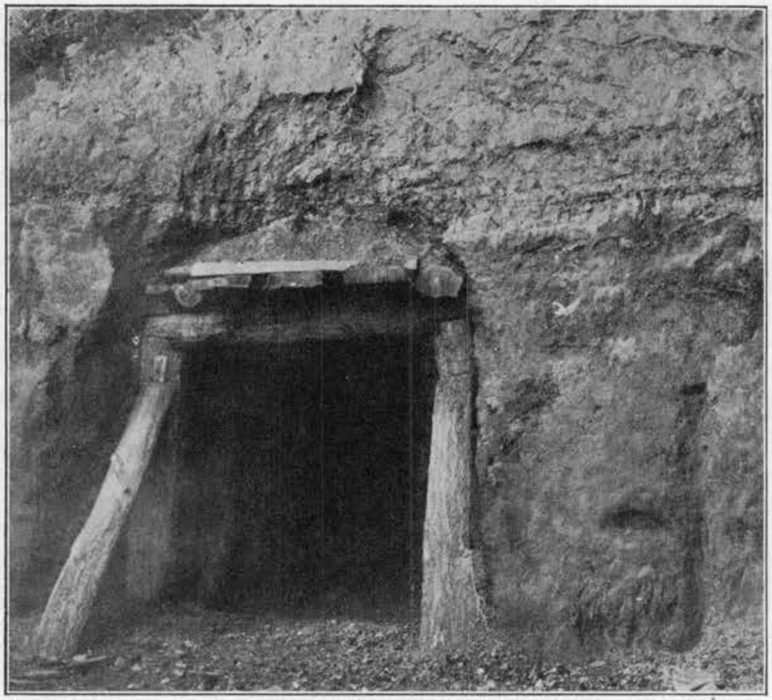
Face	Per cent Iron (dry)
7 feet	54.00
8½ feet	54.67
6 feet	54.04
7 feet	53.25
6 feet	53.78

Churn drill samples of the ore show the following:

Face	Per cent Iron (dry)	Face	Per cent Iron (dry)
10 feet	46.78	6 feet	51.62
9 feet	53.63	4½ feet	50.90
9 feet	55.00	13 feet	53.10
9 feet	51.87	6 feet	47.50
6 feet	40.05	4 feet	51.50
		10 feet	52.14

Many analyses show a phosphorus content of .65 to .85 per cent and of manganese ranging from .03 to .61 per cent. Within the limits of the 20 acres which have now been fully prospected, it is estimated there is approximately 500,000 tons of recoverable ore. There is reason to expect that prospecting will prove a continuation of the ore bed beneath the remaining portions of the Oregon Charcoal Iron Company's property that reach sufficient elevation that the ore and accompanying lava have not been worn away by erosion.

The general features of this occurrence of the iron ore are such, as in the case of the Ironcrest deposit, as to leave no question of its bog origin. Obviously it formed in a lake or pond of some extent on an early basalt land surface and was later sealed in by the oncoming of subsequent lava flows. The layer of sediment upon the ore apparently settled to the bottom of this body of water following



Ten-foot bed of iron ore overlain by clay-tuff, Oregon Charcoal Iron Company

a long period of iron precipitation. It seems probable that most of the materials of which this overlying bed is composed may have dropped from the air into this lake, as ash and other coarser ejecta, during a transition period of vigorous volcanic eruption in neighboring regions which presaged the heavy outflows of basalt with which the country was then flooded.

COLPORT DEVELOPMENT COMPANY

The holdings of this company adjoins the Oregon Charcoal Iron Company's property on the north and consists of 160 acres in the north part of section 3 and 50 acres in the southwest quarter of section 34, the former in township 3 north, and the latter in township 4 north, both in range 2 west of Willamette meridian.

The country, though deeply gashed by stream canyons, rises in this direction to a maximum altitude of 750 feet on the Colport property. A considerable portion is in standing timber.

The iron ore bed is a continuation to the northwestward of that being opened up on the above named property. The main openings on the two properties are at practically the same elevation. This fact and the position of the ore, as shown in the drill holes that have been put down, indicate likewise a general northeasterly dip which varies locally but averages about 3 degrees from the horizontal.

According to the report of Messrs. Elmer and Hogg, consulting mining and civil engineers, 15 cuts and short tunnels have been made in the ore bed and the ore has been penetrated by 24 drill holes on the Colport property. The ore is shown to run from 46.45 per cent to 56.98 per cent iron. A composite made by combining 18 average samples of the ore had the following composition:

	Per cent
Loss on ignition	14.34
Silica	3.58
Alumina	7.47
Iron (dry)	51.00
Manganese	1.24
Sulphur	.025
Phosphorus	.849
Lime	Trace

In estimating the ore blocked out on the Colport ground by the cuts, tunnels and drill holes, the engineers have assumed an average thickness of 4.95 feet running 50.24 per cent iron. On this basis there is shown to be 540,903 long tons of recoverable ore. On the remainder of the acreage under which the ore may reasonably be expected to be present, calculation gives a probable additional 955,367 long tons.

Close examination of the various exposures on the Colport tract reveal no new features of the ore bed. It is generally underlain by a soft light-colored or a variegated clay which in most instances can be seen to be the residuum from alteration of basalt into which it grades below. Above the ore there frequently appears a stratum of micaceous sandy clay that has the characteristics of a layer of sediment deposited in water. In one of the main tunnels a few feet of what appears to be an acid tuff-breccia, or possibly a bleached basaltic breccia, occurs between the ore and overlying basalt. Locally the top surface of the ore is somewhat irregular, mounds or bunches of ore having been apparently squeezed up into the overlying clay or tuff to some extent. The character of the ore and its relationship to the rocks above and below it are here, as elsewhere, such as could come about only by its having originated through deposition as bog ore. From all data available at the present time it appears likely that this bed of ore extends beyond the property boundaries of both the Oregon Charcoal Iron Co. and the Colport Development Co. Prospecting beneath the higher ground to the west and south would seem to hold the greater promise of finding more ore.

BUNKER HILL

In the southwest corner of section 31 of township 5 north, range 2 west, some prospecting has been done on a series of claims known as the Bunker Hill group. These claims are at an altitude of about 1200 feet on the north side of the divide at the head of one of the branches of Clatskanie river. Several cuts and tunnels have been made in the hillside, which show a maximum thickness of 9 feet 9 inches of ore. It is as usual, of the soft crumbling variety with variable bands of hard ore running through it. The ore here is obviously both under and overlain by weathered basalt. In a 40-foot tunnel the soft light-colored clay below can be seen to grade immediately into faded cellular basalt. The ore compares favorably in quality with that from other deposits mentioned.

Sufficient work has been done here to show the existence of a considerable body of good ore but its areal extent is not yet determined.

LADYSMITH CLAIMS

About two miles down the Clatskanie to the north from the Bunker Hill group are the Ladysmith claims in southwest section 24, township 5 north, range 3 west. Scattered pieces of hard ore occur here and at intervals to the south along the hill slopes bordering the Clatskanie gorge. A series of drill holes, pits and shafts have been sunk by which it is claimed the presence of the ore has been determined beneath about ten acres, the bed varying from 8 to 20 feet in thickness and the overburden from a few to 46 feet in depth over the ore. Where thinnest it is clay filled with basalt boulders, but as the ore passes beneath the higher slopes of the hill the overlying material is basalt in place and this continues as the country rock to higher altitudes to the west and south. Beneath the ore is a vari-colored residual clay which promptly grades into basalt within a short distance.

An estimate of 50,000 tons of ore has been made for the area thus far prospected. The limits of the ore to the north, west and south are, however, not known. Analyses of the Ladysmith ore show a high iron content and percentage of impurities comparable with the other ores that occur in the district.

It is only in the four different locations just discussed that the ore has been opened up to an extent such that its character and relationship to associated rocks can be determined. Loose pieces of the hard ore have been found in abundance in a number of other places in the basalt areas where their exact source has not yet been ascertained. Systematic prospecting will probably prove the existence of other commercial deposits.

The ore thus far prospected is distributed over four townships and is all within easy reach of established railroads or logging roads. A large part of this area has been logged off and the railroads or old grades which ramify the district would be of material advantage in the transportation problem.

The ores are generally soft and would be easily mined. The overburden is usually sufficiently heavy to necessitate some method of underground mining. The hanging and footwalls are, as a rule, of a clayey nature and would doubtless require considerable timbering. On account of the fairly uniform thickness of the beds of ore it is thought that some modification of the long-wall system of mining, such as is sometimes used in mining coal, may be found practicable. It is estimated that the ore can be mined and delivered at some point on the Columbia river at a cost not exceeding $2.00 per ton.

OTHER ORE INDICATIONS

Along the hill slope above Alder creek one mile west of north of Spitzenberg many pieces of float iron ore are to be seen. These are all hematite, in contrast to the prevailing type in the district which is limonite. The chief difference in the two ores is the absence of chemically combined water in the former which as a consequence runs correspondingly higher in iron. Limonite may be relieved of its water by heat, and it is, therefore, most logical to account for such an occurrence of hematite as the above through the dehydration of a body of limonite, probably bog ore, by its being covered over with a later flow of liquid basaltic lava.

Abundant limonite float resembling in all respects the hard ore in the various prospects already referred to occurs for a few hundred feet up the slope of the hill to the north of Milton creek in the northwest quarter of section 26, township 5 north, range 2 west. Some of the pieces are as large as boulders. The country rock is altered basalt, which outcrops in places. It is not apparent that prospecting has been done here to ascertain the source of this float or the extent of the deposit from which it may have come.

Similar float ore is found at intervals to the northwestward of the above locality for a couple of miles along the Milton creek slope of the divide. Within the loop of Milton creek and well up towards the summit of the ridge in about section 20 of the same township particularly abundant showings are reported.

Some 400 to 500 feet above the Columbia river beyond Columbia City a bed of limonite ore in the basalt has been prospected in the north part of section 18 and adjacent portions of section 7 in township 5 north, range 1 west. A series of cuts were made and holes drilled without proving the presence of a commercial quantity of ore.

The so-called "shot" soil, which is characteristic of many regions of weathering basalt has been mentioned. Considerable areas within the region mapped are covered with this type of soil. The term "shot soil" comes from the presence of small rounded "shots" which approach limonite iron ore in composition. These can in many cases be seen to be concretionary in structure and are doubtless formed in the process of disintegration of the basalt by which the soil is left as a residue. The shot soils are prevailingly reddish or some shade of brownish-red in color though at times they have a bright red hue.

In such basalt soils the percentage of iron is quite high and concentration of iron compounds may go on so far as to make even a low grade iron ore. It would not be surprising therefore if there should be found in Columbia county, in few or many places, evidences of old reddish shot soils between lava flows, which would have the appearance of possible iron ores. It might be expected that such ancient soils would be more or less compacted or hardened or possibly modified by chemical action or by the heat of the lava that rests upon them and by the coming of which they were buried.

Croppings and float from what appear to be such buried and hardened old iron-charged soils are not infrequently seen. At about 850 feet in altitude and well up towards the summit of the divide one mile nearly east of Spitzenberg much of this shot variety of iron ore crops out in the road and is scattered about. The limonite "shots" are held in a fairly hard matrix that is deep red in color; the whole having at least the superficial appearance of iron ore. The accompanying rock here is basalt of the usual type. Similar material may be seen in an old railroad cut to the south of Cox creek one-fourth mile south of Yankton. Again, two miles west of Yanktown on what is known as the Salzer place, a thin bed of siliceous shot ore is exposed. All are closely associated with the basalts and they are to be regarded as decomposition products of these lavas. Their silicification in places may be accomplished in the soil-forming process by the silica normally released in the breaking down of a basaltic rock or, more probably, by the incursion of silica bearing solutions long after the old soil mantle became entrapped within the lava layers where we now find it. Another occurrence of the buried shot soil type is on the land and near the northeast corner of the Colport Development Company property. A few feet of reddish "shot ore" was exposed here in a prospect cut. None of the showings of this class of material thus far prospected has proved to be sufficiently high in iron or large enough in quantity to be given serious consideration.

A DISCUSSION OF THE ECONOMIC FACTORS CONTROLLING THE MANUFACTURE OF IRON ON THE COLUMBIA RIVER

By DWIGHT E. WOODBRIDGE, Consulting Mining Engineer
Duluth, Minn.

The distribution of iron ores throughout the United States is more general than that of any other metallic ores; there is no state that does not contain them in considerable quantity except Florida, Idaho, Nebraska and North Dakota. From 24 to 26 states contribute their quotas to the seventy or more million tons produced annually.

Not all known deposits are available for use at present. Some carry deleterious elements such as sulphur, phosphorus, titanium, or silica, in prohibitive quantities. Some, otherwise suitable, are so far from manufacturing centers that transportation costs are excessive. Deposits sometimes lie in scattered beds in narrow veins or lenses. Others contain elements that make them undesirable for the iron requirements of the particular region in which they occur.

As the value of a unit of iron is small compared with that of other leading metals, transportation costs govern the usefulness of iron ores to a far greater extent than is the case with most other mineral substances. Price of transportation, cost of mining and quality of ore determine the worth of an iron ore mine. In other words, the value is based on three main factors: location with regard to markets; mode of occurrence; and composition. Subordinate to these factors are others that may be regarded as of local importance. None of these are absolute, but they vary in relation to each other.

An available iron ore is one that can be produced profitably by proper mining and treatment, or that can be used economically in the manufacture of some other article. Hence, an ore of low iron content may be available because of cheap transportation, easy mining, adaptability to beneficiation, or worth in metallurgical processes, whereas a far richer ore may wait indefinitely, having less favorable situation or characteristics.

Evidence of the interdependence of these factors is easily had. For instance, the ores of southwestern Utah yet remain untouched. They comprise high grade hematites and magnetites, and great quantities can be mined from surface openings without expensive equipment or preparation; but mountain ranges and great distances separate them from present large markets and the fuel question has but now been solved. The iron ores of the Sierras of California are somewhat similarly situated. On the other hand, the fossil ores of Alabama, though they average as low as 35 to 38 per cent in iron, form beds of great lateral extent, contain enough lime to be self-fluxing and lie near coking coal. In consequence they are mined to the limit of the demand for iron and steel in the region tributary to them.

Similar illustrations may be seen in many other parts of the world, and in almost every iron ore region of the United States. The supply of brown ores in the southern states is undoubtedly vast, and their mining is not difficult, yet the consumption of these ores is half what it was thirty years ago, although the iron and steel requirements of the nation have increased tenfold. Billions of tons of ideal ores exist in the interior of Brazil, but the cost of transportation still denies them use. Ores carrying 50 per cent iron lie far under the sea off the coast of Newfoundland, but as transportation is easy they are being mined thousands of feet beyond the shore line and are shipped 2500 miles to a foreign market. Enormous quantities of hydrated soft ores along the north coast of Cuba are cheaply mined and are convenient to shipping, but their moisture content and their sticky nature combine to make the cost of handling so high that they cannot be utilized as widely as might seem logical.

Another controlling factor, one of a group that may be regarded as of secondary importance, is that of allied industries. A study of freight rates on steel and iron products from the great centers of manufacture—Birmingham, Chicago and Pittsburg—shows that the country divides itself, according to lines of neutral freights, into three areas that contain surprisingly similar proportions of the total population of the United States. But the area tributary to Birmingham lacks that diversity of manufactures that has made Chicago and Pittsburg such centers of industry. This diversification can be brought about only by wider development of the south and southwest, and by an increased technical ingenuity of the people from whom the supply of labor is drawn.

Materials necessary for the making of iron are ore, flux, and fuel. The prices at which iron is sold makes it imperative that these ingredients be comparatively near at hand, or that they be assembled over efficient and inexpensive routes. In England, distances traversed by them on their journeys to blast furnaces rarely exceed 75 miles, and when converted into iron the latter is on ocean waterways, reaching all parts of the world at minimum charges. In the United States, on the other hand, distances of a thousand miles may intervene between the ore and the fuel. The average length of haul for all the iron ore consumed in this country is not far from 600 miles, while the haul for coke with which this ore is smelted is not less than 300 miles. Were it not for the vast quantities moved and the consequent refinements of transportation, the cheapness of mining and the high quality of the ore used, the United States would suffer under overwhelming handicaps.

The foregoing remarks, while they seem to be far from the subject of a discussion of the economics of the manufacture of iron on the Columbia river, nevertheless bear a very close and definite relation. It is established that a market exists along the Pacific coast for more iron than probably can be made there for many years to come. It is established that there exists near Portland a comparatively small tonnage of fairly good iron ore of a nature suitable for the making of foundry or other irons. It is probable that additional exploration will increase this tonnage to a point where abundant supplies for a commercial smelting operation can be expected. This ore can be mined at low costs, and the question of its transport to suitable furnace sites is a simple one. Flux, though not readily obtainable, probably can be had at a cost not prohibitive.

Fuel may be either soft wood, charcoal, or coke. The former, while not entirely satisfactory, is possible. More charcoal will be required per ton of iron than would be the case were it of hard woods. It is entirely practicable to make iron from soft woods fuel; no great departure from occasional former practice is involved. But, be this as it may, the use of coke is to be favored if coke is obtainable at a proper cost. It has been the hope that Alaska coals might be brought down at a low price. Perhaps this hope was unduly optimistic. It now seems certain that Australian or English coke can be had at prices varying from, say, $9.00 to perhaps $11.00 a ton, Columbia river delivery. It is stated that it is possible to make long-time contracts for Australian coke of a reasonable metallurgical quality at $10.00 a ton.

During the activity of the Oswego, Oregon, furnace of the Oswego Iron Company, prior to 1894, a very lean ore was secured from nearby banks, and this was smelted by fir charcoal fuel, 150 bushels, or probably about 2200 lbs., being the requirements per ton of iron. At that time this cost 6.5 cents a bushel, or $9.75 per ton of iron, which does not vary much from the expected cost of Australian fuel today. I cannot estimate the probable present cost of making charcoal from fir waste in that vicinity, but question if it can be as low as this old-time figure. In other words, it is improbable that fir charcoal need now be considered seriously in connection with the manufacture of pig iron on the Columbia river.

At that time the total materials cost for making iron at the Oswego furnace were said to be as follows:

Ore, 3 tons at $2.10 per ton	$ 6.30
Fuel, 150 bu. charcoal at 6.5 cents per bu.	9.75
Flux, 1 ton stone at $5.50	5.50
	$21.55

This would have brought the total cost of iron to, say, about $24 or $25 a ton. But it is entirely probable that the true cost was higher, and that the discrepancy is due to a more expensive ore.

It would seem that the cost of making iron from the ores lying to the northwest of Portland in Columbia county should now be about as follows:

Ore, 2⅓ tons at $2	$ 4.67
Fuel, 1 1-10 tons coke at $10 a ton	11.00
Flux, 1200 lbs. stone at $4 a ton	2.40
Overall charges, say	4.00
Interest on investment and amortization	1.50
	$23.57

With iron made at that cost, or approximating it, there should be a fair margin. The coast cities are now supplied from imports or from Birmingham. In both, heavy freights are an important factor in costs. No. 2 iron is now (January 1, 1923,) selling at Birmingham at about $24 a ton, on Atlantic tidewater at $27.13. A year ago southern iron sold at Birmingham at $16.00 and tidewater iron at about $24.00. These latter were very close to bottom prices. Furnace coke is now selling at Birmingham at about $6.00 a ton. These figures indicate the probable prices for competitive irons delivered at coast points.

It is evident that manufacturers in the United States must adjust themselves to the tendency to divide the country into trade zones along natural geographic and transportation lines, in order that the economic condition of the nation shall right itself. That is, long and unnecessary hauls on materials must be obviated as far as is practicable. The argument is clear that the coast should, so far as it may, become reasonably independent of distant localities on products that it can make competitively. The advantage of local manufacture of iron is clear, since it is a low-priced commodity, and the economic necessity for its use is paramount.

Commercial history shows that demand for a product grows with the cheapening of the product. While the daily requirement for iron on the coast may now be met by a small output, there is no way to determine what this demand may become ultimately, with a reduction in the price of irons.

From my own personal knowledge of the district, the result of an examination made two years ago, I can not assume that sufficient tonnage has been developed to form the foundation of an iron smelting industry, and its concomitant investments, but it is authoritatively stated that explorations prosecuted since that time have increased the known reserves of ore of commercial grade to a present total of approximately 1,500,000 tons, and that the total to be looked for is still larger.

Based on this statement it is probable that enough ore now exists to warrant an industry. The business must be approached from the viewpoint of a local manufacturing enterprise. That is to say it must be based on a pig iron unit of a size sufficient for economical operation and to return a profit commensurate to the general commercial risk plus an amortization charge to wipe out the investment during its life, all to be in addition to interest on the money invested. I feel that an iron output of, say, not less than 40,000 tons per annum, continued over a period of not less than 12 years, is about the lowest attractive possibility.

That means the daily mining of 300 to 350 tons of ore and smelting capacity of 120 to 150 tons of pig iron; or a total of about 1,500,000 tons of ore, guaranteeing an iron product of above 500,000 tons.

Whatever the truth may be as to quantities of commercial ores in the region, one fact is clear. There are several districts in the United States where iron ores, when mined, enter at once an established market zone, where all mechanical and human machinery for distribution is at hand, where sales agencies are available, where transportation is specialized, and where price quotations on ore are more or less stable and known. The Pacific coast region is not one of these. No iron in quantity is made on the coast, nor is it practicable to transport ore to places where exists the means of manipulation. The entire coast is cut off by long distances from any field in which iron-making is an established industry. Ore from the Portland district is not of a quality to command a market to which high freights are a factor. The whole question of the value of iron ores in the Portland region hinges on the local, the Pacific coast, market possibilities, providing always that there are at hand the materials out of which iron can be made on a commercial scale.

SPONGE IRON

The usual method of making iron and steel is to reduce the metal in the ore to pig iron in the blast furnace, the construction and operation of which require large capital. To make steel, impurities such as excess carbon and silicon gained in the blast furnace must be removed from the pig iron in a converter, another process necessitating heavy financial outlay.

Many attempts have been made in recent years to produce the metal (sponge iron) without going through the customary routine of smelting into pig or cast iron which requires both fuel and flux. It is obvious that if steel can be made direct by melting sponge iron in electric furnaces, with the correct amounts of carbon and other desired elements added, a much smaller plant investment would be demanded and very large operating economies could be realized.

As already pointed out, fuel and flux are to be crucial factors in the development of our Oregon iron ores. Considerable attention has therefore been given to the possibility of making sponge iron, in which neither flux nor coke would be required, but in which local coals or charcoal could be used. The commercial manufacture of sponge iron has recently been accomplished by Messrs. A. G. S. Anderson and E. B. Thornhill, metallurgists, at the Chino Copper Company, Hurley, New Mexico, where a 5-ton daily capacity furnace has been in constant operation for the past seven months.

The successful development of a process for the manufacture of sponge iron on a commercial scale is to be regarded as an exceedingly important advance in iron and steel metallurgy. Mr. Anderson has kindly prepared for publication in this report the following description of the process, the equipment employed and the results obtained:

The process was developed at the property of the Chino Copper Company at Hurley, New Mexico, by Mr. E. B. Thornhill and myself for the purpose of securing an acceptable precipitant for dissolved copper. Any kind of iron ore of a suitable grade may be used. The relative ease of reduction of various iron ores is as follows:

Pyrite calcines
Limonite
Hematite
Magnetite

The iron ore is crushed to pass 30 mesh and is mixed in the proportions of 3 iron ore : 1 reducing agent. It is preferable that the reducing agent be a partially distilled coal containing between 10 and 15 per cent volatile combustible matter, and be a non-coking coal, or a lignite. Charcoal or charred wood-waste also make an excellent reducing agent. The reducing agent is passed through a 6-mesh screen before mixing with the iron ore; therefore, a very fine slack coal may be used. It is more desirable to employ coals in which the carbon is in the amorphous condition rather than coals which approach the anthracite state and in which the carbon is more or less graphitic, because the reducing reaction will take place at a much lower temperature.

The mixture of iron ore and reducing agent is introduced into the center of a muffle type furnace with a horizontal revolving hearth which is filled with coal about 15 inches deep. The furnace is heated with fuel oil and the heat is radiated from carborundum tubes extending across and immediately over the hearth. The charge is rabbled from the center to the outside edge of the hearth by two fixed rabble arms with graphite rabble blades. It requires about 30 minutes to move the charge from the center to the outside edge of a 12-foot diameter hearth. During this period the iron ore is reduced to metallic iron.

The process is a non-slagging and non-melting operation. The iron ore is merely deoxidized to metallic iron which is really a wrought iron and is soft and malleable. The iron does not agglomerate or sinter and issues from the furnace in substantially the same sizes as it was charged as iron ore, i. e. minus 30 mesh.

The temperature employed is between 950 and 1000 degrees Centigrade. The carborundum tubes within which the fuel oil is burned are heated several hundred degrees higher.

The metallic iron, accompanied by the excess carbon used as a reducing agent and the ash from the coal and gangue from the iron ore, is rabbled off of the side of the hearth and into a water-cooled screw and thereby cooled so that it will not reoxidize when it comes into contact with the air. It is dropped from the screw conveyor onto a Dings Magnetic Separator, where the metallic iron is separated from the non-magnetic material. A small amount of ash and carbon will still remain with the iron and the product will generally average about 85 per cent metallic iron, the remainder being associated carbon and insoluble.

The reduction to the metallic state is substantially complete. If there is sulphur present, it will combine with the iron forming ferrous sulfide. Ferrous sulfide does not interfere as a precipitant for copper, in fact, it is useful. In manufacturing steel the ferrous sulfide will have to be taken into account and the sulfur eliminated in the electric furnace.

The sponge iron so produced can be briqueted into dense hard briquets without any binder. The finely divided sponge-iron or the briquets may be melted in an electric furnace to steel. The briquets may also be charged into the cupola furnace with varying percentages of scrap iron high in carbon, sulphur or other deleterious substances and used as a diluent making acceptable castings.

The cost of operating a small furnace producing an average of 5 tons of sponge-iron per day with fuel oil at $2.25 per barrel delivered; raw coal at $6.00 per ton delivered, and labor at $5.00 per shift is about $18 per ton, exclusive of the cost of the iron ore. The labor cost is about $11 per ton, but this same amount of labor will be able to produce 100 tons of sponge-iron per day as well as 5 tons per day. A furnace capable of producing 100 tons of sponge iron per day, with average cost of the principal supplies, will be able to produce sponge-iron at a cost of $10 per ton exclusive of the cost of the iron ore.

The type of a furnace capable of producing 50 tons or more of sponge-iron per day will be somewhat different in design than the small size furnaces but will employ the same basic principles.

The cost of a plant capable of producing 100 tons of sponge-iron per day is estimated to be between $250,000 and $275,000 for the furnace and if a partially distilled coal is used in preference to purchasing charcoal or charred wood-waste an additional $75,000 will be necessary for a distillation plant for the partial distillation of the non-coking coal. If the sponge-iron is to be melted into steel an additional expenditure will be necessary for the electric furnace equipment.

AN ESTIMATE REGARDING CHARCOAL PRODUCTION POSSIBILITIES IN OREGON

By O. F. Stafford, Head of the Department of Chemistry,
University of Oregon

Any proposal to establish an iron industry in Oregon must be accompanied by at least one solution of the problem of securing carbon for use as a reducing agent. The lack of adequate local deposits of coking coal makes the formulation of the problem simple enough. Either coke must be imported, whatever its cost, or charcoal must be made from local wood supplies. It is the purpose of the present chapter to forecast as nearly as may be the probable status of a charcoal producing industry, insofar as this can be done by taking into account experience elsewhere and by the use of assumed values for such local factors as are essential for the discussion.

This task is attempted with a full realization of the difficulties involved as well as of the unavoidably approximate nature of the conclusions presented. In scarcely any other industry are the factors entering into production so variable as in the charcoal or wood distillation industries. As a material for making charcoal, wood is quite as inconstant in its properties as it is for structural purposes. Yields of charcoal and of by-products are influenced by not only the species of wood used and its condition, but also by the particular carbonization method employed, by the state of repair of the appliances, as well as by the carefulness and expertness of operators. In addition to such obvious considerations as those just mentioned there are others not easily characterized but none the less influential. This is illustrated by the fact that in plants owned by the same company and under the same management, operating under apparently identical conditions but at different points, results are often obtained which are consistently unlike.

In addition to uncertainties such as the foregoing, the present discussion must also be burdened by the fact that there is no adequate local experience in the wood carbonizing industry which can be used to evaluate such factors as labor and construction costs. Even climatic conditions must be considered, and these, as well as all of the things mentioned above, are different from their counterparts in localities where this industry has been established.

In spite of the fact, however, that owing to a dearth of definite experience no precise forecast of the costs of making charcoal is possible, it is worth while to set forth the situation in as detailed a manner as may be. With the prodigious amounts of cheap waste wood available in the Northwest, it is the firm conviction of the writer that the time will soon come when amounts will be carbonized corresponding to the quantities of products which can be sold; and that, moreover, by the growth of industries at home as well as by the development of markets abroad, the demand for wood carbonization products will, before long, justify an industry of significant magnitude.

MATERIALS AVAILABLE

The materials available for charcoal manufacture in Portland territory comprise the local species of wood which figure in the lumber industry.

CHARACTERISTICS OF DOUGLAS FIR

Douglas fir is so predominant among these species that for practical purposes it may be considered the sole material. In connection with the proposed use of Douglas fir, however, it is to be remembered that fir is not considered by wood distillers to be a highly favorable material for the reason that it occupies an intermediate position between the hard woods which give a high yield of wood alcohol and acetic acid, on the one hand, and soft or resinous woods, such as southern long leaf pine, which give low yields of alcohol and acid but an exceptionally high yield of turpentine-like oils and tar. This unfortunate half-way status of Douglas fir has at times been held responsible for past failures in attempts to establish a wood carbonization industry in the Northwest. It is certain that this has been contributory to those failures, but in the opinion of the writer, only in a minor way.

WOOD SUPPLY MUST BE DEPENDABLE

The supply of wood for a charcoal industry must be absolutely dependable in the large amounts which are required. It takes practically a ton of charcoal, for example, to produce a ton of pig iron. To make the 50 tons of charcoal needed for a 50-ton per day iron furnace there must be at hand from 125 to 150 cords of wood daily, the amount depending upon the method of carbonization used and the character of the wood supply. The task of procuring an unfailing supply of wood in such amounts is of itself no simple matter and can be accomplished only through a smoothly working wood buying organization.

CORDWOOD, MILL WASTE AND STUMPS

As a practical matter the wood must be obtained either directly from the forests as cordwood or from mill waste, such as slabs or hogged wood. Proposals involving the use of stump wood as material for charcoal making can have merit only when coupled with land clearing operations of unusual magnitude which are at the same time of a character that will admit of a considerable proportion of the cost of delivering the stump wood being charged to the land. The recovery of stump wood as an operation by itself is far too expensive to compete ordinarily either with cordwood or mill residues. The utilization of stump wood, moreover, will be a more expensive matter in the plant than the use of cordwood or slabwood, although it can be handled on a cost parity with hogged wood. Stump wood frequently is rich in resin, however, and should give higher yields of oil and tar than run-of-forest material.

COST OF CORDWOOD

As regards cordwood for charcoal making there is no doubt at all that through an active wood buying organization wood can be secured in this form in any amount. The cost figure at which it must be charged to the carbonizing department of the plant will, of course, vary with conditions, lying presumably between $5.50 and $9 per cord. This cost estimate is based upon a stumpage value of 50 cents to $1 a cord; a labor cost of $1.50 per cord for cutting and stacking in the forest; a cost of from $1 to $2 per cord for delivery f. o. b. railway cars; a transportation cost of say $1 to $2 per cord with 50 cents for unloading and stacking in the yard plant; a cost of 25 cents per cord for moving from the yard stacks to the retorts; and an overhead cost of 50 cents to $1 per cord for such items as expenses of the wood buying organization, office costs, interest upon the value of the wood stored in the yard, rental of storage space, shrinkage, etc.

AMOUNT OF WOOD IN A CORD

A vital matter connected with the buying of wood by the cord, which may be mentioned at this point, is the amount of absolute wood substance to be expected in this unit. A standard cord is nominally 128 cubic feet by volume. Depending upon circumstances, however, the actual solid wood content in a standard cord will vary between 50 cubic feet and 100 cubic feet. The lower value is to be met in the case of crooked or small material. The higher figure can be expected only where the wood is in the form of perfectly straight and smooth round bolts, carefully piled so as to prevent unnecessary voids. In the literature dealing with wood measurements one most often meets with figures based upon a solid content of 70 to 72 cubic feet, this quantity being regarded as a standard cord by a majority of people. In other instances cords figure as much as 85 cubic feet, such a cord really being heavier than may be expected where split wood is in question. A tendency has lately grown among users of wood for chemical purposes such as making paper pulp, tanning extract, charcoal, etc., to assume 90 cubic feet as a standard cord. Such a cord, however, is a rare exception indeed where commercial wood is stacked in four-foot lengths and in practice is constituted of lengths ranging from 52 to 60 inches instead of 48 inches.

In making charcoal and wood distillation products with a given species of wood the yields to be obtained are determined, other things being equal, entirely by the actual amount of wood used, expressed as pounds of absolutely dry wood substance. It follows that in any discussion such as the present one it is imperative to call attention to the great variability to be met in cordwood measurements and to specify what a cord should mean. In the opinion of the writer a standard cord of four-foot wood should be defined as 83 cubic feet of solid material. Since the average specific gravity of dry Douglas fir wood is 0.52, it follows that the absolute wood substance contained in a cord of Douglas fir should weigh 2700 pounds. This corresponds to a weight of 3850 pounds where 30 per cent of the wet weight of the wood is moisture, or 4500 pounds where the moisture is 40 per cent of the wet weight.

SLABWOOD

Another possible source of wood for use in charcoal making is slabwood from the sawmills along the Columbia river. The writer has no accurate data regarding the weight of absolute wood substance to be expected in a cord of slabwood. Undoubtedly this weight will vary over wide limits, just as in the case of cordwood. In entering into any engagement to buy wood in this form it is desirable, therefore, that an exact understanding should be had with the sawmill operators to deliver the material in units which will correspond as nearly as may be to some definite amount of absolute wood substance.

Heavy slabwood delivered upon a barge, or upon the railroad cars, has a selling value approaching that of cordwood. In discussions which follow, therefore, it will be assumed that 2700 pounds of absolute wood substance in the form of wet slabwood can be delivered to the carbonizers for say $6, this figure assuming a cost of $2 per unit at the mill, $1 for loading, $1.25 for transportation, 75 cents for yarding from barge, 75 cents for overhead and 25 cents for delivering from yard to the carbonizing appliances.

HOGGED WOOD

In the systems of wood carbonization heretofore commercially operated it is necessary to use either cordwood or slabwood for the reason that until very recently no commercially feasible method of carbonizing hogged wood had been devised. Through a development of the autogenous carbonization principle, however, hogged material can now readily be converted into charcoal and its usual by-products. This method of wood carbonization is described in detail later.

The cost of hogged wood varies between $1 and $2 per so-called "unit" represented by a volume of 200 cubic feet. This unit, however, is again variable for the reason that the volume of hogged wood going into a space of 200 cubic feet will depend upon conditions attending the packing of the material. In a certain case, for example, 95 cubic feet of solid wood when hogged and shoveled loosely into a box gave 330 cubic feet. When fed into a tall tank so that the upper portions compressed the lower, the volume of this same amount of wood was 260 cubic feet; but when tamped down as it was fed into the tank, 230 cubic feet of chipped material resulted. It follows, therefore, that in dealing with hogged wood a variation of 75 per cent may be expected, depending upon circumstances. For this reason it is necessary for buyers of hogged wood to specify definitely the character of the units to be supplied. One large buyer specifies a standard unit which shall contain 2500 pounds of absolute wood substance, corresponding to a 4000-pound unit carrying $37\frac{1}{2}$ per cent of free moisture. In the neighborhood of Portland, contracts are based customarily upon an amount of hogged wood which represents approximately 2200 pounds of absolute wood substance. In the estimates to follow this Portland practice will be assumed.

CARBONIZATION PROCESSES

THE PIT PROCESS

The oldest process for making charcoal, and one which still is occasionally used, particularly where operations may be carried on to advantage at the point where the wood supply originates, is the so-called pit process. Cordwood or slabwood for this purpose is first allowed to dry for a year or so and then is stacked on end in the form of a cone-shaped pile containing usually from 40 to 60 cords. At the center of this pile an opening is left for building a fire. It is necessary before firing, however, to cover the pile with a layer of hay or leaves, and then with earth, so that air may not have free access to the wood but may penetrate only very slowly. In this way a slow combustion of a part of the mass is maintained, the heat produced serving to carbonize the rest of the material.

This process of making charcoal has the advantage of requiring little equipment, but on the other hand the expenditures for labor are excessive. Furthermore, the yield of charcoal per unit of absolute wood substance is lower than by the use of any other method and there are no valuable by-products at all. The quantity of charcoal to be expected from 2700 pounds of absolutely dry Douglas fir, by this method, would be 600 to 700 pounds, so that to produce a ton of charcoal it would be necessary to use at least 3 cords of wood. The cost for wood alone, therefore, at say $6 per cord, would be $18. Adding to this the labor and overhead costs estimated conservatively at $4 per cord, the total cost per cord becomes $10, or roughly $30 per ton of charcoal produced.

A somewhat better showing could be made by locating the char-pit operations in the forest or near a mill supplying slabs. Assuming that year-old seasoned slabs or cordwood could be had at the operating site for $3 per cord, the cost per ton of charcoal would be reduced to say $21. To this figure there must be added, of course, the cost of transporting the charcoal to the furnace.

It requires approximately three weeks to carry a single char-pit through to completion, and since the yield from a 60-cord pit would be approximately 20 tons, or a production of say a ton of charcoal per day per pit, it is seen that at least 50 pits would have to be going night and day in order to supply a 50-ton iron furnace. An organization which could maintain this number of pits in operation would itself be no inexpensive affair, so that all in all, it is difficult to see how pit charcoal could be delivered in this territory for less than $25 to $30 per ton.

A further consideration in connection with pit charring is that this is not an operation adapted to the winter climate of the Pacific

Northwest. The weather has a very considerable influence on the working of a charcoal pit and for best results operations should be conducted in the summer time when everything is dry. An all-the-year-round char-pitting operation consequently might be very difficult.

CHARCOAL KILNS

A modification of the pit method for producing charcoal is found in the use of masonry kilns. The walls of such kilns correspond substantially to the earth covering of a charcoal pit, but of course are permanent and will last a long time with little deterioration and almost negligible expenditures for repairs. A kiln is altogether too permanent and too expensive an appliance to erect in the forest, and therefore the production of charcoal by the use of kilns would have to be carried out at a central point. The capacity of a kiln may be taken as about the same as that of a pit, so that in the production of large quantities of charcoal many kilns would be necessary, the installation for a 50-ton output as a matter of fact covering acres of ground. The yield of charcoal is somewhat greater than by the pit process and it is also possible to attach a condenser to the layout, thereby saving by-products.

The cost of wood delivered to a kiln plant would be, say the figure of \$6 mentioned above. Assuming that 2½ cords of wood are required to make a ton of charcoal, it follows that the expenditure for wood alone would come to \$15 per ton of charcoal produced. Adding to this the labor and overhead charges, the total cost of charcoal production in kilns would of necessity be at least \$20 per ton.

As intimated above it is entirely feasible to conduct the vapors from a kiln to a condenser with a consequent recovery of by-products. There is, however, absolutely no dependable experience known to the writer upon which to base an estimate regarding the quantities of such by-products to be expected from Douglas fir carbonization in kilns. It is certain that some oils and tar would be obtained. Fir oil is in demand for making shingle stains, etc., while doubtless considerable quantities of tar can be sold in Pacific coast markets in competition with pine tar from the south. Indeed if only a limited wood carbonization industry ever should exist in the Northwest the tar output should command a price of 20 to 30 cents per gallon. It is conceivable that 40 gallons of tar and 5 gallons of fir oil might be recovered in kiln practice from the amount of Douglas fir required for a ton of charcoal. These products, at present, might sell for \$10 or so. It would cost something to recover them, of course, and to market them—probably half as much as their selling value. A credit of possibly \$5 per ton would in such an event become available against the cost of kiln charcoal indicated above, making the final cost something like \$15 per ton.

The use of selected wood in kilns with by-product recovery would make a still better showing, provided the additional cost of the selected material were not disproportionate. Rich stump wood, for example, should give heavier yields of oils and tar than the above estimate, but such wood is expensive both to obtain and to carbonize as compared with cordwood; its irregular condition with respect to shape of pieces, particularly, increasing all handling costs as well as decreasing the capacity of the kilns.

Finally, recurring again to the matter of selling tar, it must be remembered that the market for this commodity on the Pacific coast is limited and without question could be overstocked easily were there to be any considerable development, eventually, of the wood

Beehive charcoal ovens at former plant of Oregon Iron and Steel Company, Oswego, Oregon

carbonization industry. Consequently it would be hazardous to stake any kind of a business venture solely upon the expectation that tar will command a high price. It is probable that Douglas fir tar, produced under the right conditions, will have a future minimum value of 7 cents to 10 cents per gallon, entirely aside from any of its present uses. In estimates of its value, therefore, some such lower figure should be considered as in the long run strictly applicable.

ROUND RETORTS

In the soft wood distillation industry in the southeastern states, a type of carbonization apparatus is used which consists of an iron cylinder set horizontally in a furnace and provided with charging doors and a vapor outlet. In the south, so-called "light wood" is used for distillation, such wood being the stumps and fallen logs from forests of long leaf pine where turpentine production has been carried on for years. These stumps and tree butts are almost solid masses of resin and consequently are particularly favorable material for the production of resinous by-products. Because of this fact it is possible to carry on charcoal production in small appliances, since the by-products are more valuable than the charcoal, the latter indeed being disposed of at any possible obtainable price or even being used as fuel around the plants. It is obviously out of the question to make use of this type of carbonization apparatus with the run of material available in the Northwest, since the yields of resinous products are insignificant as compared with those from southern light wood, and charcoal here must be the principal product instead of a by-product as in the South.

OVEN RETORTS

The round retorts just described were formerly in use in the eastern parts of the United States for the destructive distillation of hard wood where the purpose was to secure wood alcohol and acetic acid rather than charcoal. Here again the charcoal was a by-product and was disposed of at very low prices or burned around the plant. Of late years, however, the tendency has been to reduce carbonization costs by use of a more economical type of appliance known as the oven retort.

The oven retort consists of a steel-plate shell of rectangular cross section usually 57 feet long, 8 feet 4 inches high and 6 feet 3 inches wide. It is provided at each end with doors which can be sealed and is suspended in a furnace so that the whole can be heated. The wood to be carbonized is loaded upon four special iron cars, each holding about 2½ cords, making the total charge for an oven ten cords. These cars are run directly into the oven, the doors are closed, and the fires in the furnaces beneath are started. Vapor outlets from the ovens are provided, these outlets leading to suitable condensers for the recovery of the liquid products of the distillation.

Usually the carbonization is completed in 20 to 22 hours so that it is possible to repeat the operation every 24 hours. The charcoal in this system remains upon the cars and is withdrawn into steel plate coolers similar in shape to the oven but built, of course, in the open air outside of the retort house. Freshly formed charcoal ignites spontaneously when exposed to air and it is necessary to let a string of four cars freshly drawn from the oven retort remain in coolers for 48 hours. This means that for each retort two such coolers must be provided in tandem if a turn of the retorts is made once each day.

Oven retorts of the kind just described represent as a matter of fact the standardized appliance of the day in wood carbonizing work. The yield of charcoal is higher than where pits or kilns are used and the recovery of by-products may be complete. Installation costs are higher than with kilns and owing to the severe heat treatment to which the steel retorts are subjected, depreciation is heavy. Nevertheless there is usually a distinct advantage in the use of ovens as against pits or kilns.

It is estimated that an installation of oven retorts at an eastern point would cost at this time approximately $3500 for each cord of wood carbonized per day, the figure including all appliances necessary for the production of calcium acetate, wood alcohol, wood oils, tar, etc., besides the charcoal. The alcohol in this case would, however, not be the refined product, but a grade known in trade as 82 per cent.

It is probable that a finished plant under this system would cost in Portland territory, because of higher costs of materials and with more expensive labor than in the East, at least $4000 per cord of daily capacity. The wood to be used necessarily would have to be either cordwood or large mill-waste, since oven retorts cannot carbonize hogged wood. The wood charged to oven retorts must be seasoned, so that it would be necessary either to store it for a year or provide a system of tunnel dryers whereby unseasoned wood might be deprived of its moisture on its way to the ovens.

The estimated cost of carbonizing fir wood in oven retorts, assuming a plant capacity of at least 100 cords per day, is as follows. In the first place the item of depreciation is heavy, amounting to as much as $1 per cord of wood carbonized. The fuel requirement is considerable also, the ovens themselves using the equivalent of 300 pounds of coal per cord, while steam and power requirements call for as much more. Labor, superintendence and other charges are such that the total costs, reckoning wood at $6 as charged to the ovens, will amount to a round figure of $18 per cord. Eight hundred pounds of charcoal, more or less, should be expected from the carbonization of 2700 pounds of absolutely dry Douglas fir, making the gross cost of producing a ton of charcoal say $45.

As a credit against this gross production figure, there might be the following values adapted from the results of experimental work with mill-run fir slabs done at Seattle some years ago jointly by the United States Bureau of Forestry and the University of Washington (a). The prices given below are assumed for this discussion as conservatively possible and so are to be taken as illustrative merely, since of course the prices actually to be obtained in any case will be matters of momentary market conditions.

8 gallons fir oil, say 75 cents per gallon	$ 6.00
10 gallons crude wood alcohol at 50 cents	5.00
70 gallons tar at 10 cents	7.00
200 pounds calcium acetate at 2½ cents a pound	5.00
	$23.00

Deducting this credit from the gross cost of $45, estimated above, it follows that the net cost of the charcoal is in the neighborhood of $22 per ton.

The investigation into yields of products from mill-run waste referred to above included also a series of tests upon selected material. The selection was determined by the appearance of the slabs, each choice showing a pitch seam or other evidence of a heavy pitch content. The proportion of this material in the entire run of slabs was 13 per cent. The yields of products reported, calculated to cor-

(a) See Journal of Industrial and Engineering Chemistry, volume 7, page 918.

respond as nearly as may be to what can be expected in the production of a ton of charcoal, are as follows, values for these items being assumed as in the example above.

20 gallons fir oil at 75 cents	$15.00
100 gallons tar at 10 cents	10.00
10 gallons crude alcohol at 50 cents	5.00
200 pounds calcium acetate at 2½ cents	5.00
	$35.00

The net cost of a ton of charcoal by use of selected material might therefore be as low as $10 per ton, provided selected slabs of the quality tested above could be charged to the ovens at a cost of $6 per cord.

CARBONIZATION OF HOGGED WOOD

The desirability of utilizing small waste wood instead of cordwood in carbonization operations has long been recognized. Literally hundreds of processes for accomplishing this objective have been proposed but for one reason or another have heretofore proved to be impracticable.

The principal difficulty encountered in the use of material such as hogged wood is that of transmitting heat to the interior of a mass of finely divided woody material. Such a mass is conspicuously a poor conductor of heat, so that only the portions of it in contact with the hot walls of a retort can in any reasonable time reach a carbonizing temperature, the central portions of the mass long remaining unaffected.

The numerous attempts to handle such material have had to do principally with overcoming this difficulty of heat transmission. Many of the projects have sought to heat the fine wood by exposing it in thin layers to the source of heat. Others have attempted to secure the necessary heat transfer by agitating the charge in the retort either by means of stirrers or by rotating the retort itself. Still others have proposed the use of a current of highly heated gas as the carrier of the heat to and through the wood mass. The almost universal failures of these efforts have in general been due to heavy costs of installing and maintaining the complicated mechanical appliances required, together with the fact that the carbonizing capacities of such installations usually are low.

A procedure has been developed during the last six years, however, which depends upon an entirely new principle. It has grown slowly through its early experimental and semi-commercial stages into commercial use at one plant having a daily capacity of nearly 100 cords, while just lately the erection of another plant of 210 cords daily capacity has been started.

This new process depends upon the fact that when perfectly dry wood is heated to the temperature at which charring begins, the carbonization then may go along to completion of its own accord without further application of heat from outside sources, the temperature of the charring mass indeed actually rising by the heat spontaneously set free in the process. This remarkable behavior of wood has been a matter of knowledge for but a relatively short time since it is exhibited only in the carbonization of perfectly dry wood, whereas heretofore the wood used for carbonization has almost always contained 20 per cent or more of moisture.

To make use of the above principle the moisture is first removed from the wod by use of a suitable dryer. The dry wood so produced goes in a continuous stream to the carbonizers. These carbonizers consist of vertical cylinders built of steel plate and lined with refractory and heat insulating materials. Valve devices permit the continuous introduction of wood at the top and withdrawal of charcoal from the bottom without introduction of air or escape of vapors. Special vapor outlets at the top connect with suitable water-cooled condensers.

The carbonization process in this type of appliance is carried on as follows: In order to obtain a suitable working temperature initially, a fire is maintained in the carbonizer for a time, whereby the interior is heated to a point somewhat above the temperature at which wood carbonization occurs. During this warming up procedure a stack valve provided for the purpose is kept open at the top while at the same time air for maintaining combustion is admitted at the bottom. As soon as the interior of the carbonizer is hot, both the stack valve and the air opening are sealed and the stream of dry wood is started.

The first portion of this stream falls upon the hot bottom of the appliance and is brought into a condition of active carbonization by the heat stored in the surrounding walls of the vessel. Meanwhile the continuous addition of incoming material has formed a layer over this active first portion. The hot vapors from beneath, filtering upward through this newly-added material, bring it in due time to a temperature of active carbonization. The heated products of this activity are in turn available for raising the temperature of new material which has been coming right along, and so on indefinitely, the process being continuous so long as properly conditioned wood is supplied. Charcoal is removed from the bottom, of course, as may be necessary.

The carbonization of hogged wood by this procedure has been proved beyond question to be commercially practicable. The carbonizer is relatively inexpensive and suffers almost negligible depreciation. Carbonizing capacities are enormous, a machine having interior measurements corresponding to 500 cubic feet of volume easily handling 100 cords per day. Yields of products correspond closely to those obtained in oven retort practice although certain products, calcium acetate particularly, appear in greater quantity.

In this system, it is to be noted, no fuel whatsoever is used to effect the actual carbonization after the process has once been initiated in the carbonizer. It is necessary, however, to burn fuel to remove the moisture from the wood to be carbonized. This drying is accomplished in rotary dryers and where hogged wood of average moisture content is handled the fuel requirement for drying is the equivalent of about 200 pounds of coal per cord of wood treated. This is substantially less fuel than is required to carbonize a cord of wood in oven retorts.

The cost of installing a plant using this continuous system is less than that of building an oven retort plant of equivalent capacity. The system in question has, moreover, a number of obvious other advantages, notable among which are low depreciation, labor, and fuel costs as compared with other systems. The fact that in this process hogged wood may be used instead of cordwood is of course a pre-eminent advantage.

Opposed to these advantages, however, is the fact that from its very nature hogged wood must produce charcoal in a finely divided state. For use in blast furnace work it is necessary that charcoal shall have certain minimum requirements as to strength and size of pieces. A small percentage of the charcoal from hogged wood might be large enough to use directly, but the major part undoubtedly would have to be briqueted for blast furnace work.

A large amount of experimental work has been done on the problem of charcoal briquet manufacture, with the result that certain processes actually are at this time operating commercially. So far as the writer knows, however, no attempt has been made to utilize charcoal briquets for making charcoal iron. Since it is easily possible to manufacture briquets which are stronger than ordinary charcoal there seems to be no reason at all why briquets might not be used in the blast furnace with entire success.

The estimated gross cost of producing a ton of charcoal briquets from hogged wood stands in the neighborhood of $38, including all overhead. The by-products will correspond closely to those indicated above for oven retorts both in quantity and kind. The assumed value of these by-products as obtained from unselected mill waste is about $23, making the estimated cost of briquets appear as $15 per ton. This figure, so far as can be seen, can be lowered, even, in proportion as selected resinous waste may be available. The briquets bring a higher price in the market than lump charcoal.

CONCLUSIONS

Douglas fir as material for making charcoal is disadvantageous as compared with certain other kinds of wood, owing to the low yields of by-products obtainable from it.

The estimated cost of a ton of charcoal from fir by char-pitting methods is in round figures $30 per ton. Char-pitting would probably be a difficult year-around operation in Oregon.

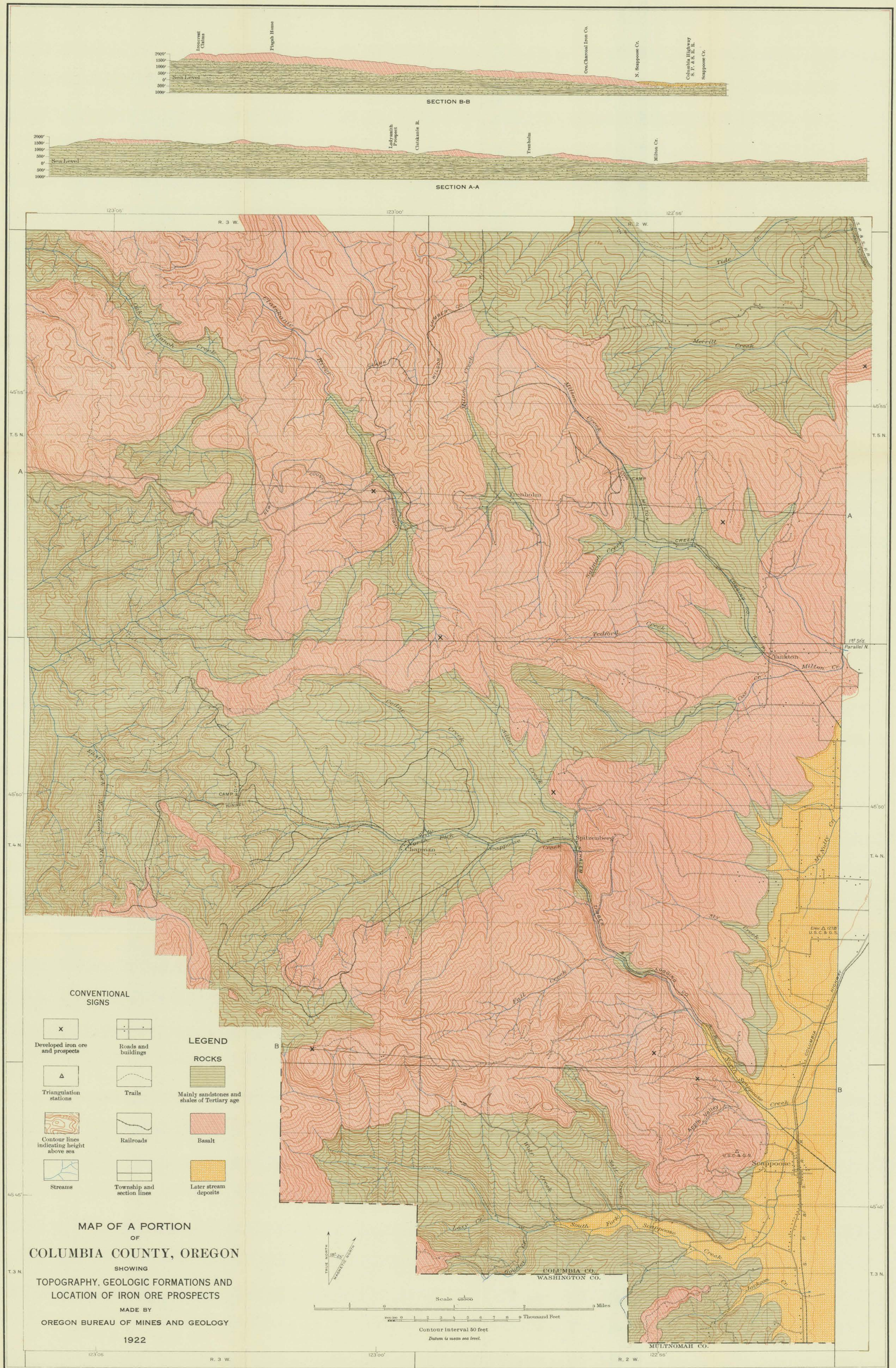
Charcoal can apparently be made in kilns, without by-product recovery, for $20 per ton. By saving and marketing by-products, the cost of charcoal possibly could be reduced to $15 per ton.

Oven retorts with by-product recovery should produce charcoal for $22, more or less, per ton.

By the use of hogged wood it is estimated that high-class charcoal briquets can be made at a cost of about $15 per ton.

All of these estimates are to be taken as approximations based upon the best information now available. No effort has been spared to make the figures as exact as possible, but absolute exactness can be secured only from established practice in the field, and such practice is non-existent. The figures therefore are merely indicative in their significance.

Copies of this report may be obtained by application to the Oregon Bureau of Mines and Geology, 417 Oregon Building, Portland, Oregon.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SECTION A-A
Sea Level
CONVENTIONAL SIGNS
Developed iron ore and prospects
Roads and buildings
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Contour lines indicating height above sea
Railroads
Streams
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LEGEND
ROCKS
Mainly sandstones and shales of Tertiary age
Basalt
Later stream deposits
MAP OF A PORTION
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COLUMBIA COUNTY, OREGON
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LOCATION OF IRON ORE PROSPECTS
MADE BY
OREGON BUREAU OF MINES AND GEOLOGY
1922
Contour interval 50 feet
Datum is mean sea level.
COLUMBIA CO.
WASHINGTON CO.
MULTNOMAH CO.
Trenholm
Yankton
Spitzenberg
Chapman
Scappoose
Milton Creek
Merrill Creek
Tide Cr.
Tedford Creek
Fall Creek
North Scappoose Creek
South Fork Scappoose Creek
Jackson Cr.
R. 3 W.
R. 2 W.
T. 5 N.
T. 4 N.
T. 3 N.