Limonite Deposits Near Scappoose Columbia County Oregon

By PRESTON E. HOTZ

A CONTRIBUTION TO ECONOMIC GEOLOGY

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A description of low-grade iron deposits of economic interest

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LIMONITE DEPOSITS NEAR SCAPPOOSE, COLUMBIA COUNTY, OREGON

By Preston E. Hotz

ABSTRACT

The Scappoose limonite deposits are in Columbia County, Oreg., 25 miles northwest of Portland. These deposits, discovered about 1860, were studied jointly by the U. S. Geological Survey and the U. S. Bureau of Mines in 1942 as part of the Strategic Minerals program.

The limonite beds are interlayered with basalts of Miocene age. The limonite, formed by intense chemical weathering of basalt, was deposited in basins and stream channels in an interval of quiescence during the effusion of the Columbia River basalts. The deposits of limonite are older than and unrelated to the laterites and ferruginous bauxite that are also found in this general area.

Five deposits are known in the basalt terrane west of Scappoose. Probably the deposits once were more extensive, but subsequent erosion has dissected the basalt and removed part of the beds and left isolated bodies beneath a protective covering of deeply weathered basalt. Eight bodies of limonite in five deposits were explored by trenching and drilling and are estimated to contain approximately 4,000,000 long tons, which average 19.7 moisture, 39.1 percent Fe, 0.037 percent S, 0.58 percent P, 0.47 percent Mn, 4.28 percent SiO_2, and 3.58 percent Al_2O_3. The limonite beds average 5 feet in thickness, and the overburden ranges from 5 to 160 feet in thickness. The deposits, though small, are a readily accessible source of iron ore, which, however, would have to be beneficiated to decrease the phosphorus content before it could be used to manufacture pig iron that would meet specifications for steel making. It might be used, however, in the manufacture of cast-iron pipe. Some of the ore has recently been mined from open pits and used for pigment, and some has been shipped to British Columbia where it was used to remove sulfur from manufactured gas.

INTRODUCTION

PURPOSE AND SCOPE

The U. S. Geological Survey in cooperation with the U. S. Bureau of Mines studied the limonite[1] deposits near Scappoose, Columbia County, Oreg., in 1942 as part of the Strategic Minerals program

[1] In this report, limonite is retained as a general field term that refers to the natural hydrous iron oxides whose real identity is unknown but most of which is probably cryptocrystalline goethite with adsorbed or capillary water. (See Palache, Berman, and Frondel, 1944, pp. 685–686.)

during World War II. The exploration was conducted by the Bureau of Mines and included trenching, test pitting, hand-auger drilling, churn drilling, and rotary-bucket drilling. The writer, representative of the Geological Survey, spent about 4 months in the field, from March to June 1942, studying the geology of the deposits. Because of the thick overburden, little areal geologic mapping was possible. Geologic interpretations were based primarily on artificial exposures in trenches and pits, and from drill-hole logs.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the aid and cooperation given by E. Y. Dougherty, J. R. Reynolds, and J. V. Kelley, of the Bureau of Mines. The work of the Geological Survey was under the direction of E. F. Burchard. S. G. Lasky advised the writer in the field.

HISTORY

Limonite deposits were discovered near Scappoose about 1860 and were rather actively explored by several operators, principally the Oregon Charcoal Iron Co. and its successor, the Oregon Iron Development Corp. Exploration consisted of drilling with churn drills and hand augers and the excavation of trenches and test pits.

The deposits have not yielded commercial iron ore, but they have evoked considerable interest from time to time because they seemed to offer a readily accessible source of iron ore. Limonite from similar deposits at Oswego, 8 miles south of Portland, was used by the Oregon Iron Co. and its successors for the production of pig iron and cast-iron pipe from about 1867 to 1895.

PREVIOUS WORK

The most comprehensive published description of the deposits is by Williams and Parks (1923). An investigation by Miller (1940) on the feasibility of a steel plant in the lower Columbia River area deals briefly with the Scappoose district. The most complete report on the geology of the general area is that on the St. Helens quadrangle by Wilkinson, Lowry, and Baldwin (1946).

Recent studies have been conducted by the Bureau of Mines, the Geological Survey, and the Oregon Department of Geology and Mineral Industries in connection with the discovery and exploration of ferruginous bauxite deposits (Libbey, Lowry, and Mason, 1944; Bell[2]; Libbey, Lowry, and Mason, 1945; 1946; Kelley, 1947), which are found in the vicinity of the Scappoose limonite deposits.

[2] Bell, G. L., Preliminary report on laterite deposits and occurrences in the Portland region, Oregon: U. S. Geol. Survey, 1945. [In open file.]

GEOGRAPHY

The Scappoose district is in southeastern Columbia County, northwestern Oregon (fig. 22). It is bounded on the south by Multnomah and Washington Counties and on the east by the Columbia River. The town of Scappoose is 25 miles northwest of Portland on the Columbia River Highway (U S 30) and the Astoria branch of the Spokane, Portland & Seattle Railway. The deposits can be reached from Scappoose by good dirt and graveled roads. Distances to the deposits from the railroad at Scappoose and St. Helens are from 1 to 15 miles. A logging railroad operated by the Clark-Wilson Lumber Co. bisects the district in an east-west direction.

The district is at the northern end of the Coast Ranges on the eastern slope and is drained by the Nehalem and Columbia Rivers. Altitudes range from 50 feet above sea level at Scappoose near the Columbia River to 2,000 feet at the divide 6 miles to the west. In this area the terraces formed by the ancient Columbia River have been intricately and, in places, deeply dissected to form very steep valleys separated by broad flat-topped ridges.

Weathering of the rocks has extended to such depths that solid rock is exposed only locally along the major streams. The whole area is covered by a thick mantle of clay and soil on which there was once an extensive growth of timber, most of which has been cut over and

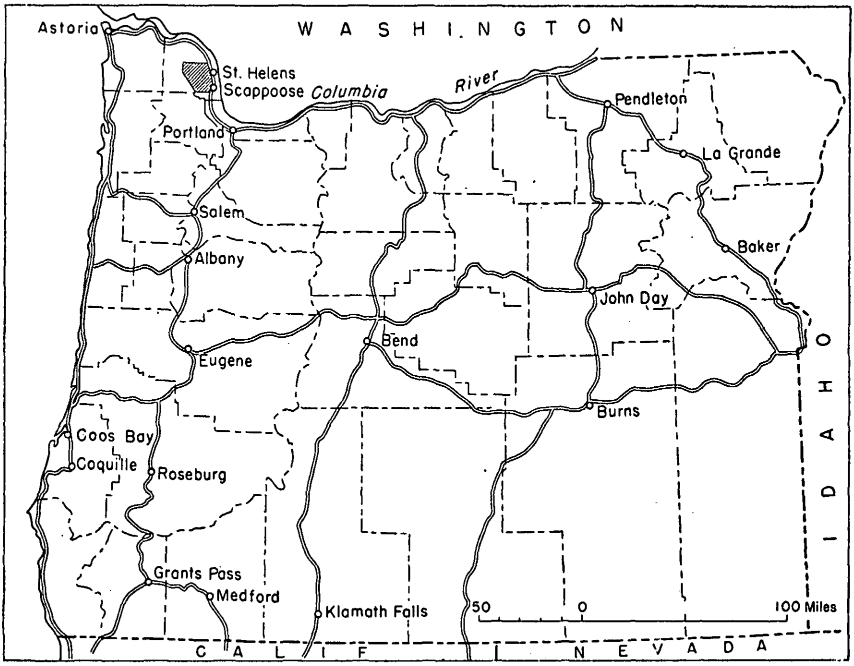

FIGURE 22.—Index map of Oregon showing the location of the Scappoose limonite deposits.

burned so that much of the region is overgrown with brush and scrubby timber.

GEOLOGY

STRATIGRAPHY

The rocks in the Scappoose district are all of Cenozoic age. The following sequence has been recognized by Wilkinson (1946, pp. 24–28) in the St. Helens quadrangle:

Rock formations in the Scappoose district Columbia County, Oreg.

Age	Formation	Description
Recent.	Alluvium.	
	Unconformity	
Pleistocene.	Terrace sands and gravels.	Portland delta stage.
	Unconformity	
Pliocene.	Troutdale.	Loosely indurated sandstone, conglomerate, silt and interbedded volcanic breccia.
	Unconformity	
Miocene.	Columbia River basalt.	Basaltic lavas and associated dikes.
	Unconformity	
Oligocene.	Oligocene sedimentary rocks.	Predominantly marine tuffaceous sandstone of Gries Ranch, Pittsburg Bluff, and possibly Blakely age.
	Unconformity	
Upper(?) Eocene.	Goble volcanic series.	Basaltic lavas, pyroclastic rocks, and associated sediments.

The Goble volcanic series is not present in the Scappoose district and is not considered in the discussion that follows. The oldest rocks in the district are sedimentary rocks of Oligocene age. These are unconformably overlain by the Miocene basalts with which the limonite deposits are associated. The basalt in most places has been reduced to decomposed rock and clay because of intensive weathering. A small patch of sediments of Troutdale age was mapped by Wilkinson north-northeast of Scappoose, but this formation was not recognized by the writer. The youngest rocks are the Pleistocene deposits of unconsolidated sand and gravel bordering the Columbia River lowlands and the Recent alluvium along the streams.

OLIGOCENE SEDIMENTARY ROCKS

Oligocene sedimentary rocks are widely exposed over the area but are found only near two of the limonite deposits. Sandstone and shale crop out on the slopes below the Miocene basalts west of Scappoose and south of the Colport-Charcoal Iron limonite deposit (pl. 8). Sedimentary rocks of Oligocene age also crop out on the slopes north and northwest of the Ironcrest deposit (pl. 9).

The rocks are mostly buff to greenish-gray tuffaceous sandstone and interbedded silty shale and include a few lenticular beds of conglomerate. The sandstone is mostly uniform, medium- to fine-grained, and massive; in many places iron oxide staining gives it a bedded appearance. The principal constituents are volcanic glass, various amounts of chalky feldspar, some quartz, and flakes of white mica; fragments of basaltic rock and pumice are visible under a hand lens.

According to Wilkinson (1946, pp. 15–18) the formation contains faunas of Gries Ranch, Pittsburg Bluff, and possibly Blakely age. He states (Wilkinson, p. 16) that "* * * probably the greater part of the Oligocene section in the St. Helens quadrangle is made up of beds of Pittsburg Bluff age * * *." Warren, Grivetti, and Norbisrath (1945) have estimated that "* * * farther west the sediments * * * have an aggregate thickness of at least 2,300 feet."

COLUMBIA RIVER BASALT

The basalt with which the limonite deposits are associated rests disconformably on the dissected surface of the Oligocene sedimentary rocks. Probably the basalt formerly covered most of the Scappoose district as a continuous sheet, but subsequent erosion has stripped it off in places and exposed the underlying sedimentary rocks.

The greatest exposed thickness of basalt in the region is at the eastern edge of the district where it is between 400 and 500 feet thick. To the west the basalt becomes thinner and the contact with the underlying sedimentary rocks is at a higher elevation. In places near the crest of the range the basalt is less than 25 feet thick.

The exploratory drilling has shown that there are at least four basalt flows (fig. 23). The contacts between individual flows are marked by an abrupt and definite change downward from brownish, fine-grained nonvesicular basalt to a brilliant red, blue, purple, and yellow variegated clay that has a relict vesicular, scoriaceous or amygdaloidal structure. Limonitic clay and traces of hard limonite and manganese oxide are present in the clay. The brilliantly hued clay was formed by weathering of the upper part of the basalt flows during an interruption in the extrusion of basalt. The intense chemical weathering at the top of the flows may have taken place in part even after the overlying sheets of basalt were laid down, because the permeable upper part of the flows permitted more active circulation of ground water than in the denser central and lower parts.

The fresh basalt is a black to dark-gray fine-grained rock that contains a few small phenocrysts of augite, small laths of plagioclase, and tiny grains of magnetite, which can be seen with a hand lens. The basalt closely resembles the Miocene flows in the Columbia River

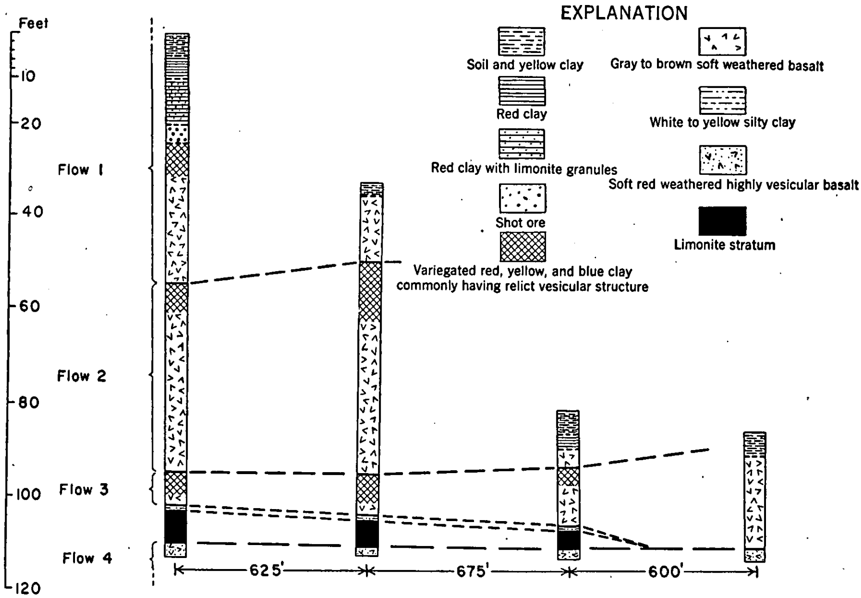

FIGURE 23.—Graphic logs of typical drill holes, Colport-Charcoal Iron deposit.

gorge and is unlike the olivine-bearing open-textured basalts of Pliocene age in the vicinity of Portland.

Weathering has affected the basalt to depths of over 150 feet in places, and there are all gradations from fresh basalt to residual clay, the final weathering product. In the least weathered product the ferromagnesian minerals are destroyed and a hard greenish-gray rock composed of a network of chalky plagioclase crystals and interstitial grains of magnetite is left. The more decomposed rock is soft and claylike, is colored with various tints of yellow, red, brown, and blue, and contains claylike limonitic material and manganese oxide. The original texture and structure of the rock are fairly well preserved. The final weathering product is a sticky red or gray clay. All evidence of the rock from which the clay was derived is gone. Pellets or "shot" of hard limonite as much as one-fourth of an inch in diameter are commonly found in this red clay.

TROUTDALE FORMATION

Hodge (1933) introduced the name Troutdale for gravels and sands deposited by the ancestral Columbia River. He considered the formation to be probably of Pleistocene age, but Chaney (1944, p. 334) considers it, on the basis of the flora, to be probably early Pliocene in age.

The Troutdale formation was not recognized by the writer in the Scappoose district, but Wilkinson shows several small areas of Troutdale sediments on his map of the St. Helens quadrangle (Wilkinson, 1946). Part of the terrace deposits shown on plate 8 may include the Troutdale formation.

TERRACE DEPOSITS

Along the Columbia River lowland, Pleistocene terrace deposits of sand and gravel overlie the basalt and sedimentary rocks. These deposits are mostly at altitudes below 400 feet. Pebbles of quartzite and basalt are found at higher elevations and may be remnants of the Troutdale formation or possibly higher terraces.

RECENT ALLUVIUM

Unconsolidated sands and gravels of Recent age are distributed along the larger streams. For the most part these deposits are clearly separable from the terrace deposits.

STRUCTURE

The Oligocene sedimentary rocks in the district have a general northerly strike and a prevailing gentle dip to the east. The basalt disconformably overlies the sedimentary rocks on a surface of moderate relief and dips gently to the east. At the Ironcrest deposit in the western part of the district the basal contact of the basalt is at an altitude of about 2,000 feet; near Scappoose the basal contact is approximately 200 feet above sea level.

Faults were not observed by the writer because of the heavy soil and vegetation cover. Wilkinson, however, noted several features in the St. Helens quadrangle that indicated faulting, but, as no conclusive evidence was obtained, "* * * no faults are shown on the geologic map." (Wilkinson, 1946, p. 33.)

ORE DEPOSITS

DISTRIBUTION

Several deposits of limonite are known in the area, and the locations of the largest bodies are shown in figure 24. The largest, the Colport-Charcoal Iron deposit, is about 2 miles west of Scappoose. The next largest, the Ironcrest body, is 8 miles west of Scappoose. The Bunker Hill and Ladysmith deposits are about 12 and 14 miles, respectively, west of St. Helens near the road to Vernonia. A small deposit, Hill 600, is on the southwest side of North Scappoose Creek approximately 3 miles northwest of Scappoose. All these deposits were explored by the Bureau of Mines. A sixth, on Alder Creek about 1 mile northwest of Spitzenberg, was also explored. Some boulders of hematite were found at the surface and in bulldozer trenches, but exploration failed to show any in place.

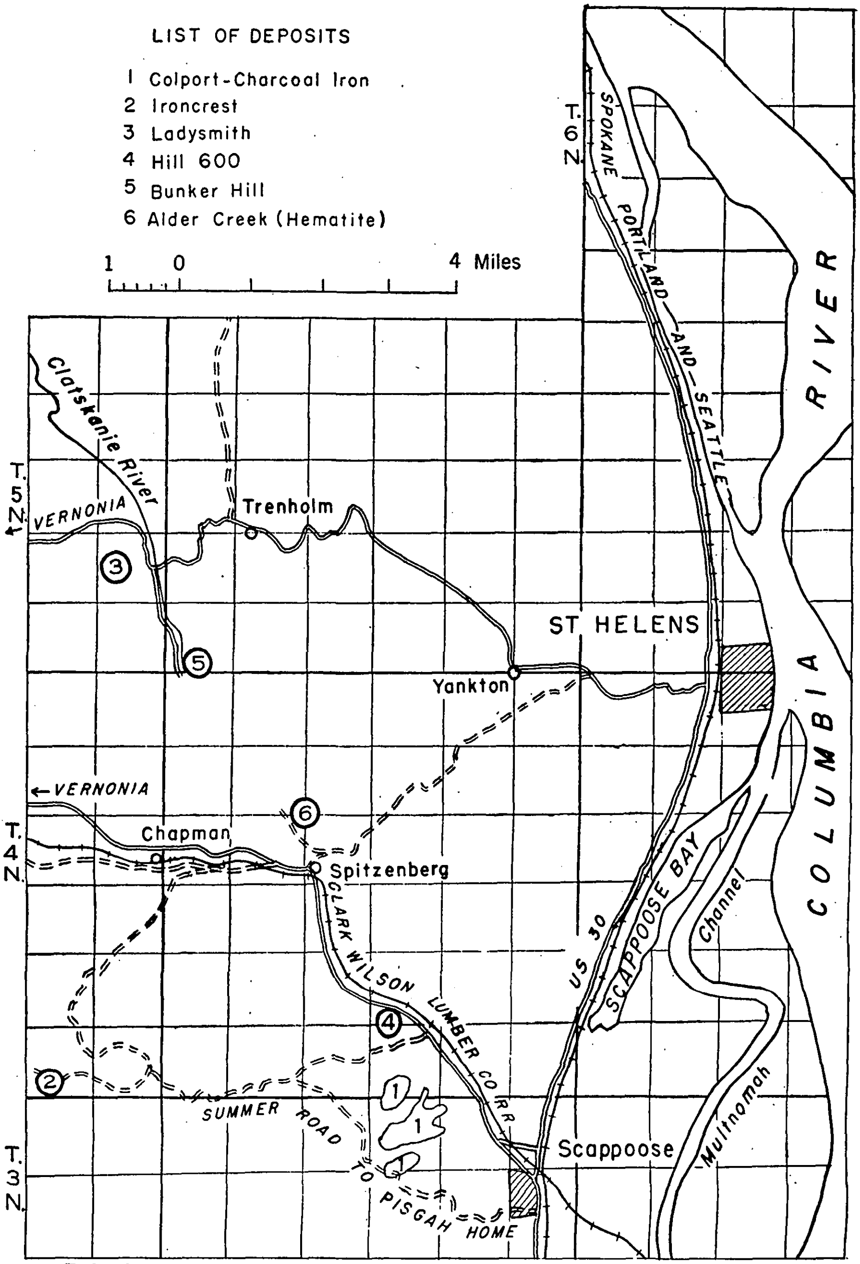

FIGURE 24.—Sketch map showing location of limonite deposits near Scappoose, Oreg.

RELATIONSHIP TO FERRUGINOUS BAUXITE DEPOSITS

Blankets of ferruginous bauxite are found on the surface of the basalt terrane in the Scappoose district and elsewhere in several counties of northwestern Oregon, principally in Washington, Columbia, and Marion Counties. Descriptions of the bauxite deposits are contained in reports by Libbey (1944, 1946), Bell (1945), and Kelly (1947). They are younger than the limonite deposits that are interbedded with the basalts. According to Wilkinson (1946, p. 23), the bauxite deposits were formed "before the deposition of silty sediments which (locally) disconformably overlie the basalt and ferruginous bauxite. These sediments are tentatively assigned to the upper part of the Troutdale formation of Pliocene age." The ferruginous bauxite represents the product of extreme weathering and leaching of the basalt.

STRUCTURE OF THE LIMONITE DEPOSITS

The limonite deposits are within the basalt sequence between two flows, and in any single deposit the stratum of limonite is between the same two flows. (See fig. 23.) For example, the three separate bodies of limonite at the Colport-Charcoal Iron deposit are between the same two flows. Furthermore, where the limonite stratum is missing, the contact of the two flows between which it occurs elsewhere is recognizable. Possibly, though not certainly, all the limonite deposits occupy the same stratigraphic position. Their history suggests that they were formed simultaneously throughout the region during an interval between two periods of basalt extrusion.

Assuming a single stratum of limonite in a given deposit, the distance of the limonite stratum above the underlying sedimentary rocks depends upon the thickness of the underlying basalt, which in turn depends on the configuration of the surface on the Oligocene sediments and the tendency of the basalt to thin in a westerly direction. The thickness of any single deposit varies from place to place owing in part to erosion prior to burial and in part to original differences in thickness.

Normal faults of small displacement cut the deposits in places but do not affect the distribution or continuity of the limonite stratum.

The largest stratum, at the Colport-Charcoal Iron deposit, has a general strike to the northwest and a northeasterly dip of about 4°. In detail, however, dip and strike range widely from this general attitude. Along the northeastern and southwestern boundaries of the deposit the dip increases, and the limonite bed becomes thinner and pinches out altogether. The Ironcrest, Bunker Hill, and Ladysmith deposits are channellike or lenslike with a thick central part, and they thin out abruptly along the edges.

COMPOSITION AND GRADE

Three varieties of limonite (see footnote, p. 75) are found in the deposits (fig. 25). The most common variety is locally designated hard or granular ore and is composed chiefly of large irregularly shaped granules of hard lustrous black limonite in yellow clay. In general the ore is dark brown to yellow brown, and locally it has a wine-red tinge. In places the limonite granules are spongy, and the cavities are either open or partly filled with yellow clay. The cavities are outlined by delicate banding in the limonite.

A second variety, called soft ore, most commonly underlies the hard or granular ore as a definite stratum, though it may be found as lenticular bodies in the hard ore. This variety is composed of claylike or sandy material that binds together tiny angular grains of hard black limonite as much as 2 millimeters in diameter.

Distinct layers or veins of hard brittle massive and lustrous black limonite as much as 6 inches thick occur in both the hard and soft ore strata. They may be either parallel to or transgress the bedding. The veins or layers are confined to the ore beds and do not pass into the wall rocks.

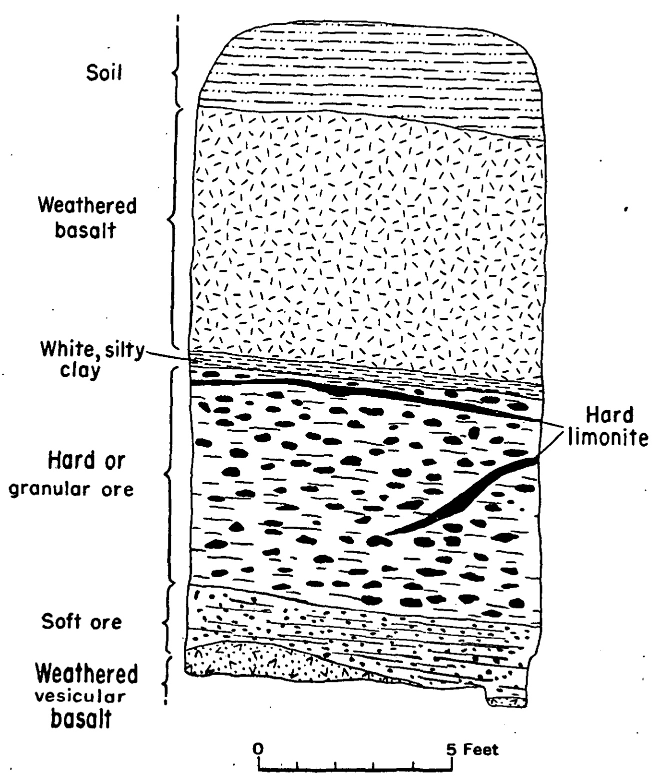

FIGURE 25.—Sketch of a typical exposure of the limonite bed at the Colport-Charcoal Iron deposit.

Foreign rock particles generally are absent from the limonite bed, though such material may be present as microscopic grains. In a few exposures angular and subangular blocks of vesicular footwall basalt are within the beds near the lower contact.

The limonite stratum is 1 to 18 feet thick and is overlain and underlain by basalt or its weathered derivative. The base of the deposit rests on soft almost completely decomposed highly vesicular basalt that is stained brilliant red, yellow, and blue. The deposit is overlain at most places by a light-colored silty clay that is capped by weathered basalt as much as 150 feet thick. The contact between the limonite bed and the underlying basalt is slightly irregular and sharp, though a suggestion of gradation is visible at places. The contact between the deposit and the overlying silty clay is characteristically sharp, but it may be irregular and show channeled structures. At the Ironcrest deposit the relations are reversed and a bed of white clay separates the limonite bed from the underlying basalt, whereas the upper basalt rests directly on the deposit.

The deposits appear to be stratified in places, but the apparent stratification is not necessarily an original depositional feature because it could be due to selective solution and redeposition of the iron.

The ore contains from 40 to 59 percent iron, a high content of phosphorous, high silica, and some manganese. The soft variety generally assays 2 or 3 percent higher in iron than the granular ore. Moisture content and ignition loss are both high. Analyses of Scappoose ore listed by Zapffe (1949, pp. 57, 59) show a 0.4 percent ZnO content. Partial analyses by the U. S. Bureau of Mines of composite samples of the three varieties of ore are presented in the following table together with analyses of mixtures of granular and soft ore. The average iron content of each deposit is somewhat lower than the samples listed. The second table lists the average composition of each deposit.

Partial analyses of different varieties of limonite ore (dry basis)

[Analyses from U. S. Bureau of Mines. Analyst: Lerch Bros., Hibbing, Minn.]

	1	2	3	4	5
Ignition loss	12.37	11.60	10.37	13.25	13.78
Fe	52.49	55.00	59.76	50.18	40.92
P	.99	.98	.24	.67	.42
Mn	.27	.35	.09	.24	.22
SiO_2	4.60	3.18	1.18	7.28	15.62
Al_2O_3	4.90	2.12	.81	5.86	10.68
S	.04	.03	.02	.03	.03
TiO_2	1.30	.19	.08		
CaO	.06	.05	.06	.04	.07
MgO	.13	.22	.10	.11	.13

1. Composite of 9 samples of granular ore.
2. Composite of 7 samples of soft ore.
3. Selected specimen of hard limonite.
4. Composite of 5 samples of granular ore mixed with some soft ore.
5. Composite of 5 samples of soft ore mixed with some granular ore.

Average partial analyses of limonite

[Analyses from U. S. Bureau of Mines. Analyst, Lerch Bros., Hibbing, Minn.]

Deposit	Moisture	Ignition loss	Fe	S	P	Mn	SiO_2	Al_2O_3	TiO_2
Natural basis, percent									
Colport-Charcoal Iron	19.5	10.5	39.0	0.02	0.62	0.50	4.07	3.65	--------
Ironcrest	20.8	10.28	39.36	.07	.36	.26	5.46	1.80	--------
Ladysmith	19.5	10.04	39.88	.10	.56	--------	4.58	3.18	0.32
Bunker Hill	21.8	9.90	35.85	.13	.57	--------	3.84	4.35	--------
Hill 600	20.0	8.80	39.80	.03	.71	.52	4.61	6.25	.32

Deposit	Ignition loss	Fe	S	P	Mn	SiO_2	Al_2O_3	TiO_2
Dry basis, percent								
Colport-Charcoal Iron	13.04	48.4	0.03	0.77	0.62	5.05	4.53	--------
Ironcrest	12.98	49.7	.08	.46	.33	6.89	2.27	--------
Ladysmith	12.47	49.5	.13	.69	--------	5.69	3.95	0.40
Bunker Hill	12.66	45.8	.17	.73	--------	4.91	5.05	--------
Hill 600	11.09	49.8	.03	.89	.65	5.77	7.81	--------

ORIGIN

The limonite deposits were formed under conditions of intense chemical weathering during an interruption in the extrusion of basalt. The iron-bearing minerals of the basalt were decomposed and the iron was converted to ferrous salts, which were carried away by streams and moving ground water; some of it probably remained behind as residual limonite. The evidence indicates that the limonite deposits are not residual, but that they formed in a subaqueous environment.

Probably at the time of formation of the limonite deposits the terrain was one of low relief with sluggish streams, ponds, and swamps on its surface. To these sites the ferrous salts were transported in solution or as colloids and were precipitated and oxidized to ferric hydroxide. Some residual limonite that formed by weathering of the basalt also may have been washed into the basins of deposition as a sediment. Fine silty and clayey sediments transported by the streams were deposited along with the limonite. Locally, movement and reworking of the limonite continued after its deposition, as at Ironcrest where the deposit is stratified and contains interbedded tuffaceous lenses and petrified wood fragments. The light-colored silty clay that overlies the bed at most of the deposits probably was tuffaceous material that fell in or was washed in rapidly after the limonite deposits had formed. At Ironcrest the limonite bed was deposited on a rhyolitic tuff.

Renewed outpourings of lava interrupted the formation of the limonite deposits and covered and protected them from erosion. The basalt above the deposits was deeply weathered and on its surface a fairly extensive mantle of laterite and ferruginous bauxite was formed, remnants of which are found today (Libbey, Lowry, and Mason, 1945, p. 14). The protective cover of basalt was subsequently breached and parts of the once more extensive limonite beds have been destroyed by erosion.

DESCRIPTION OF DEPOSITS

COLPORT-CHARCOAL IRON DEPOSIT

The largest deposit in the Scappoose district is the Colport-Charcoal Iron deposit, which derives its name from the titles of the two development companies that did the original work on the deposit some 30 years ago. The companies have since been dissolved and the land is now divided among several owners.

The deposit was discovered in 1898 but was not much explored until about 1920 when the Oregon Charcoal Iron Co. excavated several short tunnels and open-cuts along the outcrop, most of which were reopened during the recent exploratory program. In 1922 several churn-drill holes were put down to explore the extent of the deposit.

The deposit is 1½ to 2 miles northwest of Scappoose (fig. 24). It is in sec. 3, the NW¼ sec. 2, and the NW¼ sec. 10, T. 3 N., R. 2 W., and the S½ sec. 34, T. 4 N., R. 2 W. The area is readily accessible from Scappoose either by the Pisgah Home summer road or the road up Apple Valley. From these main routes of travel, logging roads which may or may not be still usable, penetrate deeper into the area. During the exploration the Bureau of Mines put in several miles of bulldozer road which, however, is now probably impassable to motor traffic.

The deposit consists of three separate strata of limonite beneath three broad northeast-trending ridges separated by deep ravines (pl 8). The limonite strata are from 500 to 900 feet above sea level and at an average altitude of 600 feet above the floor of the Columbia River valley. The deposit is not exposed at the surface because of the heavy mantle of soil and vegetation and was visible only in open-cuts and exploratory tunnels. The drill holes and open-cuts and the distribution of the limonite bed are shown on plate 8.

The limonite deposit is between two weathered basalt flows and is about 500 feet above the contact of the basalt with the underlying sedimentary rocks. It is underlain by a soft brilliant red clay that has a well-preserved vesicular structure and is overlain by soft white silty clay that in turn is capped by fine-grained weathered basalt. In places the limonite bed is absent and only the white clay containing particles of limonite is present. The thickness of the limonite bed varies considerably over the whole area, ranging from 1 to 13 feet and having an average thickness of 5 feet. The overburden, which is clay and soft weathered basalt, is from 4 to 160 feet thick.

The southeasternmost part of the deposit is known as the South Ridge body. This narrow and tonguelike deposit is about 3,200 feet long and from 100 to 800 feet wide. The limonite stratum trends northeast; the bedding strikes generally northwest and dips from 4° to 15° NE. The dip increases toward the southwest end. The inclination of the stratum is slightly greater than the slope of the ridge top so that to the southwest the deposit is progressively nearer the surface (pl. 8, sec. *E–E′*). The limonite stratum also thins toward the southwest and feathers out at the southwest end. The overburden ranges in thickness from more than 90 feet at the northeast end to as little as 5 feet at the southwest.

About 2,000 feet north of the South Ridge body and separated from it by a narrow, deep ravine, is a parallel broad flat ridge that splits into three narrower ridges at its northeast end (pl. 8). This is known as the Tabor or Middle Ridge and the deposit beneath, the largest of the three, is called the Middle Ridge body. The overburden of soil, clay, and weathered basalt above the limonite bed is as much as 145 feet thick, though toward the southwest and northeast ends it is less than 100 feet thick. The outline of the deposit is irregular in shape because of erosion. The deposit dips to the northeast; the dip is gentle in the northeast part but steepens toward the southwest end of the ridge. The stratum pinches out on the northeast beneath the ridge (pl. 8, sec. *D–D′*). It is exposed at the southwest end but the extension could not be found beneath the higher ridge to the southwest, though the silty clay and the soft red vesicular basalt of the footwall were found in drill and auger holes.

Approximately 2,000 feet northwest of Middle Ridge and separated from it by a deep, narrow stream valley, is another broad ridge referred to as North Ridge (pl. 8). Beneath it is the third and northernmost body of limonite of the Colport-Charcoal Iron deposit. The stratum of limonite trends northeast and dips in the same direction except near its northeast termination, where the dip is to the southwest. It pinches out before reaching the surface on the northeast and northwest ends of the ridge as well as beneath the narrow part of the ridge on the southwest (pl. 8, sec. *C–C′*). The overburden is nearly 160 feet thick in places.

HILL 600

The Hill 600 deposit is in the southern part of the SW¼ sec. 27, T. 4 N., R. 2 W., about 1 mile north of the Colport-Charcoal Iron area (fig. 24). The body may be a remnant of the north extension of the Colport-Charcoal Iron deposit. Reopening of old cuts, the excavation of new ones, and exploration with hand augers disclosed a small isolated bed of limonite at an altitude of about 600 feet (pl. 9).

The limonite bed is nearly 900 feet long and averages about 300 feet in width; the long dimension trends east-west. It dips southwest at a low angle. The deposit ranges from less than 1 foot to a maximum of 5½ feet thick and averages a little more than 3 feet.

The deposit contains both granular and soft ore. In places erosion prior to burial by basalt has removed the deposit, and yellow silty clay containing fragments of limonite was deposited in place of the ore.

The central part of the deposit was not explored by drilling, so its continuity beneath the hill is not established.

IRONCREST DEPOSIT

The Ironcrest deposit (pl. 10) is in the southern part of sec. 35, T. 4 N., R. 3 W., about 8 miles by road from Scappoose (fig. 24). It is near the crest of a ridge at an altitude of between 2,000 and 2,100 feet. The area is accessible either by the road from near Chapman or the summer road to Pisgah Home from Scappoose.

The deposit was discovered in 1918 and the western part was rather thoroughly explored by short adits and open-cuts. A stratum of limonite of uncertain dimensions to the east was indicated by a few test pits. The deposit was explored in 1942 by the Bureau of Mines, which reopened the old cuts and drilled test holes with power drills and hand augers. The locations of the open-cuts and test holes are shown on plate 10.

The limonite bed is interbedded with basalt and is from 30 to 50 feet above the contact of the basalt with the underlying Oligocene sedimentary rocks (pl. 10, sec. *B–B′*). This contact, which dips gently to the south, is exposed near the top of the steep slope on the north side of the ridge.

The deposit is about 2,600 feet long and trends east-west. The western part is narrow and stringlike because its northern half was removed by erosion. This part averages about 75 feet in width, whereas the eastern part, which is not exposed at the surface, is about 400 feet wide. The body is lenticular in cross section (pl. 10, sec. *B–B′*, *C–C′*, *D–D′*, *E–E′*), and its central part is as much as 15 or 18 feet thick. Its northern and southern boundaries are sharp where the limonite stratum thins out abruptly. This is especially noticeable in the excavations in the western part. The limits of the deposit are fairly well defined. The eastern part averages almost 12 feet in thickness whereas the narrow western part, owing to its extreme variability, averages only about 7½ feet.

The ore is a mixture of the granular and soft types and the former is predominant; in places it is sandy. The bed contains a few layers of hard black limonite 4 to 6 inches thick and several feet long. At most places the deposit is separated from the underlying basalt by a layer of soft white clay a few inches to 5 feet thick. This clay, which appears to be a weathered rhyolitic tuff, rests on highly vesicular weathered and leached basalt. In a few places, as along the southern edge of the deposit, the limonite stratum rests directly on decomposed basalt. The deposit is overlain by fine-grained basalt, which is less weathered than at the other deposits.

The stratified appearance of the limonite bed, abundance of enclosed fragments of petrified wood, superposition of the bed on rhyolitic tuff, and lenses of tuffaceous clay are evidence for a sedimentary rather than a residual origin of the deposit. The shape of the deposit suggests that the limonite was deposited by surface waters in a channel-like depression, possibly along a stream.

LADYSMITH DEPOSIT

The Ladysmith deposit (pl. 11) is about 14 miles west of St. Helens on the St. Helens-Vernonia road in the SW¼ sec. 24 and the NW¼ sec. 25, T. 5 N., R. 3 W. (fig. 24). The deposit has been prospected by a series of cuts where it crops out along a slope on the west side of a small stream. The deposit was discovered at about the same time as the Ironcrest body.

The exploratory drill holes put down by the Bureau of Mines, and the interpretation of the form of the deposit are shown on plate 11.

The deposit forms two small bodies, one on the northwest side and one on the southeast side of a small valley. The northwest body is the larger and is elongate in a northeast-southwest direction; its greatest dimension is 1,160 feet and its width is approximately 500 feet. The smaller body is at the crest of a ridge that is southeast of the larger body. This deposit averages only about 100 feet in width, less than 800 feet in length, and ranges from 2 to 14 feet in thickness. In plan the deposit is crescent-shaped. Both bodies are lenticular in cross section. (See sections, pl. 11.)

The ore is similar to that in the other deposits. It is interbedded with flows of weathered basalt and lies upon soft red cellular clay; white silty clay lies between the ore and the overlying weathered basalt, which is as much as 40 feet thick.

BUNKER HILL DEPOSIT

The Bunker Hill deposit (pl. 12) is at an altitude of about 1,200 feet on the north side of the divide at the head of one of the branches of the Clatskanie River. It is in the S½ sec. 31, T. 5 N., R. 2 W., and is about 12 miles west of St. Helens (fig. 24). The deposit is accessible by poor dirt road from the Vernonia-St. Helens road.

The deposit consists of four small remnants of a narrow channel-like body that crops out in a few places but elsewhere is beneath a maximum of 30 feet of weathered basalt. The deposit lies upon weathered vesicular basalt and is overlain by yellowish silty clay. The thickness of the limonite stratum varies considerably and probably averages 5 feet. A small thin blanket of ferruginous bauxite was discovered near the end of a low ridge in sec. 6, T. 4 N., R. 2 W.

POSSIBILITY OF FINDING NEW DEPOSITS

As much of the district is covered by basalt (Wilkinson, 1946, geologic map), the possibility of discovering new bedded deposits of limonite cannot be ruled out. Prospecting for new deposits will, however, be difficult because of the brushiness of the area and the thick cover of soil and weathered basalt. Probably the most favorable places to look for new deposits are along fresh road cuts or areas where recent logging operations have cleared away some of the soil cover. The most promising areas appear to be in the 4½ miles or so between the Colport-Charcoal Iron and Ironcrest deposits, and south of Spitzenberg in secs. 20, 28, 29 and 30, T. 4 N., R. 2 W., and secs. 25, 26, and 30, T. 4 N., R. 3 W. The basalt may be as much as 500 feet thick in places here, and a deposit or deposits similar to the known ones might be found between two flows. Much of the northern part of the district west and northwest of Yankton is covered by basalt and might also be prospected successfully.

Magnetic methods of prospecting have not been used in this area so far as is known, and they probably would not be successful. Any magnetic effect that the limonite deposits might have would be masked by the stronger over-all attraction caused by the basalt.

ECONOMIC CONSIDERATIONS

The only commercial production of iron from the limonite deposits in northwestern Oregon has been from a deposit near Oswego, south of Portland, from 1867 to 1894. It would be desirable to have a local source of ore to supply the iron foundries and steel plants in the Pacific Northwest. The Scappoose deposits, however, are relatively small, and also would require treatment by some process of beneficiation to lower materially the phosphorus content, which is too high to make pig iron that could be used satisfactorily in the manufacture of steel. The deposits might be utilized, though, as a source of iron that would be suitable for the direct casting of iron pipe. Ore from Oswego was once used in such an industry. In 1945, 20 carloads of ore from the Ironcrest deposit were shipped to California for paint pigment (Wilkinson, 1946, p. 37). In 1949 some limonite was mined from an open-pit on the Charcoal Iron property and was shipped to

British Columbia for use in removing sulfur from manufactured gas.

The total reserves in the deposits described are estimated to be approximately 4,000,000 long tons of iron ore. The small amount of overburden at Ironcrest makes that deposit favorable for open-cut mining. At the Colport-Charcoal Iron deposit the overburden is too thick and the limonite deposit too thin to make open-cut mining methods feasible, and underground methods of mining would probably have to be employed.

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