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DIVISION OF MINES AND MINING
SHELDON L. GLOVER, Supervisor

Report of Investigations
No. 7

Manganese Deposits of the Olympic Peninsula, Washington

By
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FOREWORD

The manganese deposits of the Olympic Peninsula, Washington, have been of marked interest to prospectors and miners, industrialists and private mineral investigators, and State and Federal agencies since their first recognition in about 1915. Detailed studies were begun in 1918, when the Washington Geological Survey examined the Tubal Cain mine and the U. S. Geological Survey investigated occurrences in the Skokomish River drainage. The work was continued by the State agency in 1920, and, by the U. S. Bureau of Mines and U. S. Geological Survey, in 1925. The undersigned examined several occurrences in 1925 and 1926, and began a regional study of the peninsula, including the manganese-bearing formation, for the State Division of Geology in 1934, a study that was supplemented by additional detailed investigations of specific manganese occurrences by the Division of Geology in a subsequent year.

In 1934 and 1935 certain deposits were investigated as projects of the Federal Civil Works Administration and the Washington Emergency Relief Administration; following this, during 1937-1940, a more intensive survey was undertaken by the Federal Works Progress Administration under the sponsorship of the State Department of Conservation and Development and Department of Public Lands. Also, a very detailed investigation by the U. S. Geological Survey was begun in 1938 and continued during 1939-1940, and the U. S. Bureau of Mines, in 1940, explored a few deposits by diamond drilling. Finally, several deposits, particularly in the Quinault and Skokomish areas, were again visited in 1942 and 1944 by members of the staff of the State Division of Mines and Mining, and some experimental geophysical work was done on one deposit.

The Division of Mines and Mining issued a mimeographed report by J. W. Melrose in 1940, giving a summary of the unpublished reports of the mineral investigation project of the Works Progress Administration. The demand for this was large, and the edition was soon exhausted. The present Report of Investigations, prepared in response to a large number of requests, includes all pertinent information given in the earlier paper, brings the material up to date, and includes hitherto unpublished data from the files and from in-investigations made by Sheldon L. Glover, W. A. G. Bennett, and Ward Carithers of the Division staff. In order to make the report as useful and comprehensive as possible, the U. S. Geological Survey bulletins have been freely drawn upon, and quoted when that appeared the most useful procedure. It is hoped that this material from so many sources will supply in one report the data most generally desired on a resource of known value and one thought to be of yet greater potential value.

SHELDON L. GLOVER, Supervisor,
Division of Mines and Mining

April 10, 1945

MANGANESE DEPOSITS OF THE OLYMPIC PENINSULA, WASHINGTON

By STEPHEN H. GREEN

INTRODUCTION

The Olympic Peninsula forms the northwestern corner of the State. It is bounded on the west by the Pacific Ocean, on the north by the Strait of Juan de Fuca, on the east by Hood Canal and Puget Sound, and on the south by the lowlands drained by the Chehalis River and some of its tributaries. Except on its margins, the peninsula is of relatively high relief. The Olympic Mountains rise abruptly from the lower, marginal area and reach altitudes up to and in excess of 7,000 feet; the altitude of Mount Olympus, the highest peak, is 7,954 feet. High cliffs, vertical-walled canyons, and serrated ridges are common. Topographic details of the peninsula may be obtained from the quadrangle maps of the U. S. Geological Survey and U. S. Army.

The climate is relatively mild, and the precipitation is very heavy. In the winter, snow accumulates in areas above 4,000 feet to so great a depth that much of it remains throughout the summer in the form of drifts, avalanche heaps, and small but active glaciers. Numerous lakes and ponds are distributed between the main ridges, and swift, cascading streams are abundant. Owing in large measure to the prevailing climatic conditions, one of the largest stands of Douglas fir, spruce, hemlock, and other conifers remaining in the United States covers the slopes of the mountains. The close spacing and huge size of many of these trees are features equaled in few other places.

The Olympic Highway entirely encircles the peninsula, and numerous side roads follow major drainage channels into the mountains from the main highway. Several logging railroads are in operation on the peninsula. Trails serve other parts of the region, but where roads and trails are lacking the area is very difficult of of access.

The peninsula is of particular economic interest because of the occurrence of manganese. The deposits, with few exceptions, are confined to a belt varying from 1 to approximately 16 miles in width and about 145 miles in length that lies on the outer slopes of the mountains on the north, south, and east. For the most part they are within the heavily timbered area below an altitude of 4,000 feet. At some places, however, the deposits are at higher altitudes; for example, at the Black and White mine, on the North Fork of the Skokomish River, they occur at about 4,000 feet; at the Tubal Cain mine, on Iron Mountain, at 6,500 feet; and on the southern flank of Mount Constance, at 5,200 feet.

That manganese occurred in the peninsula was probably first discovered in 1880 when a deposit was found near Lake Cushman, in Mason County. Recorded locations were not made, however, until 1889, when prospectors reported manganese and iron, presumably on the Skokomish River and in the vicinity of the original discovery. Thereafter, other occurrences were discovered in Mason, Jefferson, and Clallam Counties, associated with sparse copper mineralization which was then of chief interest to prospectors. By 1910 some development was underway, again for copper, though by 1915 interest was shifting to manganese; and in 1917-18 several manganese bodies were being explored, and shipments, chiefly for experimental purposes, were made from properties in the Skokomish River area. It was not until 1921 that the predominant manganese-bearing ore of the peninsula region was definitely recognized as bementite.[1] Subsequent investigations have shown its wide distribution in the area, together with neotocite, hausmannite, and other manganese minerals.

FIELD WORK AND ACKNOWLEDGMENTS

The information on manganese occurrences, contained in this report, has been largely obtained from investigations made during the strategic-mineral surveys conducted by the Civil Works Administration and Washington Emergency Relief Administration in the years 1934-1935, and from the 4 years extensive work done by the Works Progress Administration, when crews including as many as 75 men were employed in stripping and trenching the various outcrops of manganese minerals on the peninsula. The writer was a Field Engineer during the earlier work and Field Supervisor in charge of most of the later investigations. At those times were gathered most of the data used herein. I take pleasure in here acknowledging the help and many courtesies extended to me by the late Charles W. Greenlee and Chris. Morgenroth, also Ed. N. Brooks, H. W. Brooks, H. W. Pollock, Theodore F. Rixon, J. M. Fitzgerald, T. T. Aldwell, Arthur Coventon, C. S. Anderson, Arnold Levy, and many others, as well as especial appreciation to Sheldon L. Glover, Supervisor, and W. A. G. Bennett, Geologist, Division of Mines and Mining, for their assistance in the preparation and editing of this report.

U. S. Geological Survey reports, State reports, and others have been freely consulted and some data taken from them. Credit for such information is given in each case in the footnote references.

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[1] Pardee, J. T., Larsen, E. S., Jr., and Steiger, George, Bementite and neotocite from western Washington, with conclusions as to the identity of bementite and caryopolite: Washington Acad. Sci. Jour., vol. 11, pp. 25-32, 1921.

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GENERAL PRODUCTION AND USES OF MANGANESE

Manganese is an essential metal in the manufacture of steel, approximately 14 pounds being required for every ton of steel produced; it is therefore of the utmost importance both in times of war and peace. It is also used in a large number of ferrous and nonferrous alloys, these various metallurgical requirements accounting for more than 90 percent of the manganese ores used in the United States. Some manganese is used in the battery industry, and small amounts are used in the manufacture of oxygen, chlorine, bromine, and disinfectants; it is also used as a coloring agent in glass and ceramics, as a gas purifier, and as a dryer in paints and paint pigments.

Prior to the first world war, the manganese production of the United States was less than 1 percent of requirements, and from 1909 to 1918 an average of 350,000 long tons was imported annually from foreign sources. During the first world war, domestic ores were more fully drawn upon, and these to a larger extent supplied the needs of the industry; but when the war ended, domestic production declined to its previous status, owing to higher costs, lower grade in comparison to imported ore, and the uncertainty of a continuous supply.

In the 10 years from 1932 to 1941, the average annual importation of manganese ores amounted to 640,000 long tons. A renewed interest in domestic sources of supply was brought about by the outbreak of the present war. It was expected that transportation difficulties would arise, and that some foreign sources would be cut off, so that again it was of the utmost importance to assure a continuing supply of this vital metal from domestic sources. As a result, old deposits were reopened, new occurrences developed, and detailed studies made of potentially productive areas.

Imports of high-grade manganese ore into the United States ①
(long tons)

Year	Cuba 47.4	Brazil 43.5	Gold Coast 51	India 49.8	Philippines 48.	South Africa 47.2	U. S. S. R. (Russia) 51.9	Other countries	Total general imports
1931......	3,804	133,927	87,439	47,850	....	....	195,834	33,664	502,518
1932......	6,749	21,500	24,592	1,750	....	....	55,437	606	110,634
1933......	28,257	None	43,768	None	....	....	83,780	1,030	156,835
1934......	63,743	55,834	73,656	20,550	....	....	124,836	2,720	281,234
1935......	43,955	29,528	95,134	56,570	500	....	153,200	5,114	371,089
1936......	37,876	110,018	241,593	126,913	....	100	289,867	7,095	761,441
1937......	122,937	77,988	254,547	70,380	....	209	383,949	1,910	1,226,777
1938......	131,422	29,698	126,857	25,480	4,002	....	166,042	85	644,344
1939......	105,936	42,713	242,924	89,545	6,966	3,401	135,243	7,386	698,487
1940......	130,646	168,241	246,983	189,473	43,515	177,739	311,748	13,734	1,294,278
1941......	164,819	208,970	138,301	149,604	46,274	45,818	28,122	12,608	853,190

① Mineral Industry, vol. 50, p. 358, 1941.
(Figures under country names indicate the manganese content of recent ore imports.)

Manganese ore production in the United States ①
(long tons)

Year	Metallurgical ore	Battery ore	Miscellaneous ores	Total high-grade ore	10–35 percent ore	5–10 percent ore	Manganiferous zinc residuum
1932....	9,963	7,012	802	17,777	15,635	9,799	69,802
1933....	9,527	7,904	1,715	19,146	12,779	178,852	69,304
1934....	14,978	8,889	2,647	26,514	23,231	198,591	105,111
1935....	16,679	7,264	2,485	26,428	93,291	430,893	109,127
1936....	18,557	7,747	5,815	32,119	98,962	841,557	125,566
1937....	26,419	6,447	7,375	40,241	151,955	1,189,017	130,427
1938....	16,989	4,959	3,373	25,321	33,620	275,240	113,200
1939....	18,580	7,767	2,960	29,307	239,544	469,703	153,250
1940....	27,158	9,271	3,694	40,123	320,006	816,541	174,594
1941....	65,930	10,178	2,271	78,379	459,000	820,000	251,829
1942....	158,898	13,759	419	173,076	237,199	1,339,833	260,760
1943....	174,193	11,343	93	185,629	418,627	1,117,209	241,364

① Mineral Industry, vol. 50, p. 354, 1941; also U. S. Bur. Mines Mineral Market reports, no. 1266, January, 1944.

PRINCIPAL ECONOMIC MANGANESE MINERALS

Although more than 100 minerals contain manganese, only a few of these, mostly oxides, are commercially important. The silicates braunite ($4MnO.3MnO_2.SiO_2$) and rhodonite ($MnO.SiO_2$), containing 63.6 and 41.9 percent of manganese, respectively, have little or no present importance as manganese ores. Bementite ($8MnO.5H_2O.7SiO_2$), another silicate (see page 16), is new to industry but is expected to have definite commercial value.

Prinicipal economic manganese minerals

Mineral	Composition	Percentage of manganese
Franklinite	$(Fe, Zn, Mn)O.(Fe, Mn)_2O_3$	Variable
Hausmannite	$MnO.Mn_2O_3$	72.05
Manganite	$Mn_2O_3.H_2O$	62.4
Psilomelane	$MnO_2.Mn_2O_3$ (variable)	45–60
Pyrolusite	$MnO_2.nH_2O$	60–63.2
Rhodochrosite	$MnCO_3$	47.6
Wad	Hydrous impure mixture of manganese oxides	5–50

GEOLOGY

The mountainous central part of the Olympic Peninsula, an area of about 2,000 square miles, is predominantly composed of a thick series of sedimentary rocks that has been closely and complexly folded. Argillite and graywacke are the usual rock types, and these, in many places have been metamorphosed to slaty, quartzitic, and even schistose variants. Granite and other plutonic rock types have not been found and are not thought to occur, though occasional infolded or downfaulted remnants of later, volcanic, rocks are present. The age of this central mass is in doubt, but the available evidence, admittedly inadequate, indicates a pre-Tertiary, probably late Mesozoic, age.

Stratigraphically above the rocks of the central area, and exposed by erosion as a belt surrounding it on the north, east, and south, is an immense thickness of interbedded basalt, tuff, agglomerate, argillite, graywacke, and occasional limestone. This belt is indicated on plate 1 as the area between the dashed lines printed in red. The manganese deposits are associated with these rocks, giving them a special economic importance. Weaver [1] has applied the name of Metchosin volcanics to this series, correlating it with similar rocks of lower to middle Eocene age that occur on Vancouver Island. Later study by Park,[2] on a basis of a sparse fossil fauna, essentially substantiates Weaver's age determination in placing it as early middle Eocene.

Stratigraphically above the main volcanic series, and cropping out still farther from the central area, are shales, sandstones, conglomerates, and minor occurrences of volcanic rocks of younger Tertiary age. These rocks are at lower elevations than the older formations, hence where erosion is less active, and are commonly concealed by Pleistocene sedimentary deposits.

The Metchosin volcanic formation is, in general, well exposed and easily prospected. It crops out as steeply dipping, vertical, and even overturned beds in the many canyons and valleys of streams flowing from the central Olympic Mountains, and it forms peaks, steep-sided ridges, and cliffs between streams. A dense cover of moss, vines, shrubs, and timber conceals the formation in many places; soil and talus, also, may hinder prospecting; but good exposures are sufficiently abundant to permit much worth-while surface exploration to be carried on.

The manganese deposits occur as veinlike, tabular bodies mostly comformable to the adjacent bedding, as irregular pods and lenses,

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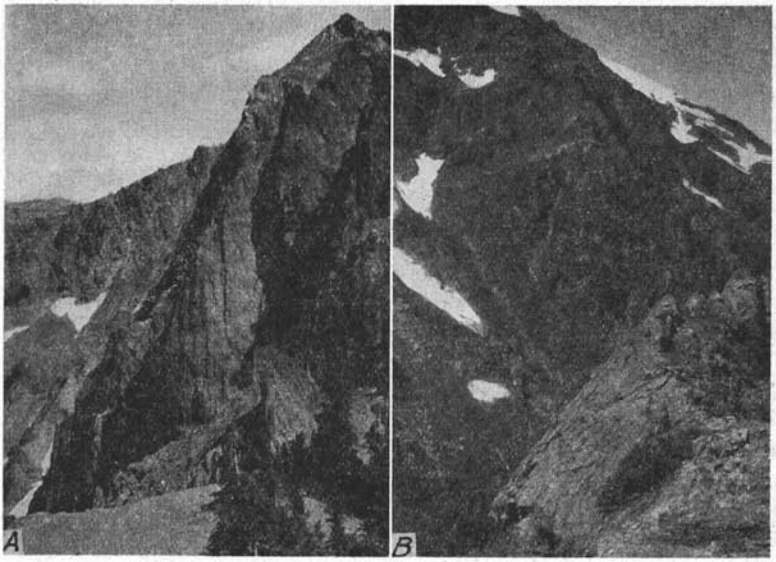
[1] Weaver, C. E., Tertiary stratigraphy of western Washington and northwestern Oregon: Washington Univ. [Seattle] Pub. in Geology, vol. 4, pp. 26-29, 1937.

[2] Park, C. F., Jr., Manganese resources of the Olympia Peninsula, Washington: U. S. Geol. Survey Bull. 931-R, p. 439, 1942.



A, B. Mount Seattle.
Precipitous slopes, typical of the more rugged part of the Olympic Mountains.

C. First development of the Crescent ore body. Main openings of the Crescent mine in 1925.

D. Typical vegetation and talus of deep valleys in the Metchosin volcanic formation.

and occasionally as dikelike masses. Widths may vary from a fraction of an inch to 30 feet or so, and lengths of 500 feet without interruption are known. Much greater lengths doubtless exist, but, unless continuously exposed, it is not safe to assume continuity between exposures, even though the strike and physical characteristics of separate outcrops indicate that only one body is involved. Commonly, the deposits pinch and swell or occur as isolated lenticular masses in the plane of strike and dip. Faulting, also, adds to the complexity of occurrence.

The manganese bodies always are associated with basalt and related effusive rocks, now mostly altered to greenstone and, in some places, serpentine. Very fine grained limestone and brown calcareous argillite are other usual accompanying rock varieties. A given manganese body may be entirely in basalt, or entirely in limestone or argillite that is stratigraphically near basalt, or it may be at contacts of such rocks. These relationships are a distinct aid in prospecting.

The limestone is unusual in many respects. It is widely distributed through the Metchosin volcanic formation, though seldom forming continuous or particularly large bodies. The known beds are nonfossiliferous, markedly siliceous, and commonly argillaceous. The iron content may be high. In texture, the limestone is particularly fine grained—porcelaneous in general; it is hard, very brittle, and breaks with a conchoidal fracture. Most exposures are maroon-colored, apparently owing to an original content of ferric iron; but in some places brown tones are a result of weathering and the unaltered rock is a distinct bluish or greenish gray in color.

The beds vary in thickness from an inch or so to scores of feet, and commonly occur as pods and lenses and as faulted, dislocated layers between the basalt flows. Other occurrences are associated with argillite, that itself may be calcareous and ferruginous and which is also associated with the flows of basalt. In most instances the accompanying basalt—or greenstone—has a pillow structure indicating a submarine origin.

Similar limestone-basalt associations have been investigated by Kania,[1] and his conclusions appear sufficiently pertinent to warrant quoting in some detail.

"Seawater under ordinary conditions is virtually saturated with [carbon-dioxide] CO_2. The abstraction of CO_2 from the sea water is the main factor responsible for the precipitation of [calcium carbonate] $CaCO_3$, and is effected by the heating and agitating of the water by a hypothetical submarine lava flow of reasonable dimensions and duration. A lava flow 20 square miles in area and 100 feet thick, issuing at a temperature of 900° C. and accompanied by the usual gas emissions from both the lava and the vent, was calculated

[1] Kania, J. E. A., Precipitation of limestone by submarine vents, fumeroles, and lava flows: Am. Jour. Sci., 5th ser., vol. 18, pp. 347-359, 1929.

to be capable of precipitating a mass of limestone equal to 191 circular lenses, each 500 feet in diameter and 50 feet thick. Since the gases given off during this eruption were found to be responsible for 90 percent, the lava alone only for 10 percent of this precipitation, a similar submarine vent intermittently giving off only gases during a period of a million years was considered. Due to the heating of the sea water by these gases it is calculated that a mass of limestone 1,000 feet thick, extending over an area of 7,000 square miles, could be precipitated. The volume of the condensed vapor from these gases was found to be equal to a sea 1,000 feet deep and 1,700 miles square. * * *

"Information shows that other factors besides those favorable for the precipitation of lime carbonate must come into play to give a deposit of any appreciable thickness. The first of these factors is based on the fact that, as the heated waters rise from the lava flow and spread out at the top, a new supply of water will come in below from the sides, augmenting tremendously the supply of $CaCO_3$ available for precipitation within a given area.

"By experiment it was demonstrated that the $CaCO_3$ precipitate, aided by the agitation produced by the convection currents and the escaping gas bubbles, would tend to settle only in the hollows and depressions on the surface of the lava flow, forming more or less discontinuous lenses of limestone of considerable thickness. The frequent occurrence of intercalated limestone lenses in lava flows may be recalled. It will have been noticed that only about 3 percent of the limestone precipitated is due directly to the lava flow and the gases given off by it, and that 97 percent of the limestone is due entirely to the gases given off from a comparatively small vent active for a very short period indeed, in geological sense. * * *

"Assuming a vent intermittently emitting only gases, and no lava, at the rate of 5 lineal feet per second for, say 25 days a year for a million years. At this rate the ocean currents need not exceed 2.4 feet per hour in order to replenish the $CaCO_3$ supply by introduction of new sea water about the area in question. Using the figure of 15.6 inches * * * of limestone precipitated over an area of 20 square miles by the vent being active for only a 100 days, this vent would precipitate limestone equal to a deposit 1,000 feet thick extending over an area of about * * * 83 miles square.

"The vent need not be covered up and stopped by this deposit because the precipitate may be carried several miles to the leeward, so to speak, of the vent by the ocean currents.

"The above is cited merely to call attention to the tremendous deposits of limestone that may be deposited by this cause, in which case we would have no lava flow to suggest to us the reason for the precipitation. * * *

"It is conceivable that, due to the altered temperature conditions of the sea water as well as to a probable unfavorable change in its composition due to such gases [sulphur dioxide, hydrogen chloride and ammonia] * * * going into solution in rather large quantities, sessile organisms in the area would be killed and preserved as fossils, whereas other organisms would shun the area and subsequent beds of limestone might, on the whole, be rather devoid of fossils other than planktonic forms.

"In conclusion the writer would like to point out that throughout geological history, there occur interbedded limestone and lava flows; periods of intense volcanic activity, submarine lava flows, and, hence, submarine vents such as the Archaeozoic are also marked by a tremendous development of limestones, which are, in the main, nonfossiliferous.

"Thick beds of limestone are known to occur between submarine cones in the lesser Antilles. All such limestones may obviously be deposited in either deep or shallow water."

MINERALOGY

The predominant manganese mineral in most of the ore bodies of the peninsula is bementite, but at the Crescent mine, the Peggy, Hurricane, Beaver Creek, and Mother Lode claims hausmannite predominates, and further exploration will probably disclose other deposits of this oxide. Bementite is an unusual silicate of manganese having been found in only a few localities other than the Olympic Peninsula. According to Pardee [1] "Locally the bementite rock is cut by veinlets * * * that contain one or more of the minerals quartz, calcite, manganocalcite, rhodonite (pink silicate of manganese), rhodochrosite (manganese carbonate), and manganophyllite (manganese mica). Under the microscope the bementite is seen to be in very fine felted aggregates of fibers or plates. Quartz, rhodonite, and manganocalcite are intergrown with it and also deposited in veinlets that cut it. * * * Specimens * * * [from several deposits] contain veinlets of neotocite, a dark-brown to black mineral having a resinous lustre * * *. Neotocite is a silicate of manganese closely related to bementite * * *. A rather striking feature of the bementite rock is its local association with native copper."

At the principal hausmannite occurrence, that of the Crescent mine, this oxide is described by Pardee [2] as showing, "aggregates of fine black grains that are commonly distributed through a brown or pinkish-brown groundmass. The aggregates take the form of bands, that in places are finely crenulated or mamillated, of irregular isolated patches, and of veinlets cutting both. A large mass of nearly pure hausmannite was exposed in the floor of No. 3 adit near the entrance. This material was dense, blue-black, and very finely crystalline."

The complexity of the mineralization in the usual occurrence of manganese minerals is indicated by the wide variation in analyses of samples from typical exposures (see table on p. 45). The metallic manganese content may vary from 5 to 32 percent, or, if manganese oxides are present, to much higher amounts. The average manganese content of 96 analyses of representative bementite occurrences is 22.39 percent. Selected samples of hausmannite contain

[1] Pardee, J. T., Deposits of manganese ore in Montana, Utah, Oregon, and Washington: U. S. Geol. Survey Bull. 725-C, pp. 234, 235, 1921.

[2] Pardee, J. T., Manganese-bearing deposits near Lake Crescent and Humptulips, Washington: U. S. Geol. Survey Bull. 795-A, p. 17, 1927.

as much as 66 percent manganese, and mine-run ore commonly has a 52 percent manganese content. Iron is present in all samples: the usual hausmannite ore has from 1½ to 2 percent; the purest bementite has about 3¼ percent; and the average of 118 samples, of which 8 include hausmannite intermixtures, is 15.7 percent. Some occurrences are particularly high in iron, as for example certain ones on Aurora Ridge (near the headwaters of Barnes Creek) and near Lake Cushman; in fact the iron content may be such that the mineral in a given exposure is manganiferous magnetite (see pp. 36-38). Equal variations are shown in the silica (SiO_2) content: selected oxides may contain very little; commercial hausmannite, 7 to 10 percent; relatively pure bementite, about 40 percent; the average of 118 samples is 28.3 percent; and far higher amounts may be present if free quartz is included in the sample. Other elements may be present such as magnesium, calcium, and aluminum, but these are usually very minor constituents of the ores.

The principal manganese minerals of the peninsula, listed in approximately their order of abundance are:

BEMENTITE

Composition.—Hydrous manganese silicate. The formula commonly given is $8MnO.5H_2O.7SiO_2$; accordingly, the theoretical amount of metallic manganese contained in bementite is 41 percent. However, only 32 percent (41.58 percent MnO) can be obtained by an analysis of a fairly pure sample.[1] This discrepancy is due to the inclusion of iron, magnesium, calcium, and zinc with the content of magnesium in deriving the formula from sample analyses. Some of these elements are obvious impurities; some, as iron, may be isomorphous with manganese. The formula $6MnO.2FeO.5H_2O.7SiO_2$, (in which magnesium, calcium, and aluminum are arbitrarily included with iron) may be more representative of Olympic Peninsula bementite, giving 30.5 percent metallic manganese as the content of the theoretically pure mineral, an amount more in keeping with analyses.

Structure.—Usually finely crystalline; fine fibers and plates. Hand samples appear massive.

Physical properties.—Hardness, 5.5-6. Specific gravity, 2.98-3.106. Tough; breaks with splintery fracture. Fresh bementite varies in color from light yellowish gray to greyish brown. Dull to vitreous luster. Transparent to translucent in thin splinters, but weathers dark, dull, and opaque.

Occurrence.—A rare mineral except in the Olympic Peninsula, where it comprises most of the manganese mineralization.

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[1] Pardee, J. T., Larsen, E. S., Jr., and Steiger, George, Bementite and neotocite from western Washington, with conclusions as to the identity of bementite and caryopolite: Washington Acad. Sci. Jour. vol. 11, pp. 28-29, 1921.

HAUSMANNITE

Composition.—Manganese oxide. $MnO.Mn_2O_3$. Metallic manganese, 72.05 percent.

Structure.—Finely crystalline, dense, massive, to aggregates of fine black grains, particles strongly coherent.

Physical properties.—Hardness, 5-5.5. Specific gravity, 4.856. Varies from darker shades of brown to blue-black in color. Luster submetallic. Streak, chestnut-brown.

Occurrence.—In a few known large, minable masses, and also as veinlets in bementite.

NEOTOCITE

Composition.—Hydrous manganese silicate. $MnO.SiO_2.nH_2O$. Composition variable; metallic manganese is less than 30 percent.

Structure.—Amorphous.

Physical properties.—Hardness, about 4. Specific gravity, 2.6. Brittle; breaks with conchoidal fracture. Color varies from reddish-brown to jet-black. Resinous luster. Usually translucent.

Occurrence.—Usually occurs in small masses and as veinlets cutting the bementite; may be more abundant than is now realized.

INESITE

Composition.—Hydrous manganese-calcium silicate. $H_2(Mn,Ca)_6Si_6O_{19}.3H_2O$. Metallic manganese, approximately 30 percent.

Structure.—Crystals small, prismatic; fibrous and radiated.

Physical properties.—Hardness, 6. Specific gravity, 3.029. Color, rose- to flesh-red.

Occurrence.—As veinlets cutting bementite but particularly as a selvage between hausmannite and wall rocks in parts of the Crescent mine (see pp. 30-31). The mineral has been confused with rhodochrosite because of its pink color. Probably rare.

RHODOCHROSITE

Composition.—Manganese protocarbonate. $MnCO_3$. Metallic manganese, 47.6 percent.

Structure.—Occurs as massive to granular-massive and compact; also globular and botryoidal; incrusting.

Physical properties.—Hardness, 3.5-4.5. Specific gravity, 3.45-3.60+. Vitreous to pearly luster. Dark-red, rose-red, yellowish, gray, fawn-colored, brown. Translucent to subtranslucent.

Occurrence.—Reported to occur as veins or veinlets in other manganese minerals. Probably rare.

RHODONITE

Composition.—Manganese metasilicate. $MnSiO_3$. Metallic manganese, 41.9 percent.

Structure.—Cleavable to compact; granular; massive; and as embedded disseminated grains.

Physical properties.—Hardness, 5.5-6.5. Specific gravity, 3.4-3.68. Brittle. Vitreous to dull luster; rose-red, pink, to brown in color. Often coated with black manganese oxide from exposure. Transparent to translucent.

Occurrence.—As veinlets cutting through, or as crystals embedded in, bementite. Probably rare.

MINOR MANGANESE MINERALS

Minor manganese minerals reported by various investigators to occur with the more abundant manganese minerals of the peninsula are tephroite (?) (Mn_2SiO_4), manganophyllite (manganese-bearing biotite, composition variable), manganocalcite ($MnCO_3$), piedmontite ($HCa_2(Al, Mn)_3Si_3O_{13}$), and jacobsite ($MgO.Fe_2O_3.(Mn, Fe)O.Fe_2O_3$).

WEATHERING PRODUCTS

Common manganese oxides such as pyrolusite ($MnO_2.nH_2O$) and probably manganite ($Mn_2O_3.H_2O$) are a feature of all occurrences. They form as an oxidation product of bementite or other manganese minerals on the outcrop, producing the black color that characterizes all exposures. This oxidation effect may be only a surficial skin, or it may have a thickness of several inches over the exposure, or it may extend for several feet along joints or shear planes. As these oxides may contain as much as 63 percent manganese, surface samples give an erroneous idea of the average manganese content of the body.

ASSOCIATED MINERALS

Associated minerals of the deposits include jasper (SiO_2 + iron oxide), which is abundant at some places. Care should be taken to distinguish jasper from neotocite, which also may be reddish in color. Other associated minerals, usually minor in amount, are: quartz (SiO_2), calcite ($CaCO_3$), laumontite ($(Ca, Na_2)Al_2Si_4O_{12}.4H_2O$), thomsonite ($(Ca, Na_2)Al_2Si_2O_8.2\frac{1}{2}H_2O$), barite ($BaSO_4$), cinnabar ($H_2S$), native copper, and various iron and copper oxides and sulphides. In places, quartz is associated with the manganese minerals as a mass of intersecting veinlets enclosing material that is largely iron oxide. Sometimes these veinlets and iron oxide form a more-or-less cellular mass having a thickness of several feet along one or both sides of the manganese deposit and may grade into the ore body. Because of structural conditions the quartzose material may apparently overlie the manganese and be considered to have been formed after the manganese minerals were deposited. In this way it is sometimes called "cap rock" by prospectors.

ORIGIN OF DEPOSITS

The manganese deposits of the peninsula are unusual in many respects, and their origin is not adequately explained by established concepts of ore deposition. Features to be taken into account by any theory of origin are: (1) the widespread distribution of certain minerals which elsewhere are relatively rare, (2) their persistent occurrence with basalt and limestone of a certain formation and nonoccurrence in adjacent formations, (3) peculiarities of mineral associations, and (4) the appearance of a bedded or depositional characteristic, without proof of replacement, in some deposits, and clear evidence of replacement in other deposits, (5) field evidence of mineralization prior to the uplift of the Olympic Mountains.

Pardee[1] at first considered the deposits to be the result of regional metamorphism of manganiferous marine sediments; then in a later report[2] he suggested an origin involving the following sequence of events:

"1. Deposition of a marine manganiferous sediment now represented by the red limestone, the manganese probably being in the form of carbonate.

"2. Eruption of a basaltic lava, forming a thick cover over the sediment.

"3. Emanation of silica as a final phase of volcanism, the silica probably being carried in solution by circulating waters expressed from the lava or of deeper magmatic origin.

"4. Chemical reactions between the limestone and silica-bearing solutions, which resulted in converting much of the manganese carbonate to bementite and replacing the limestone with that substance, the heat present being sufficient to produce or facilitate hydrothermal action. Excess silica replaced the limestone in the form of quartz ('caprock'). These reactions occurred under the lava cover, where oxygen was deficient. Locally, however, there was a small supply of oxygen available, which permitted the formation of hausmannite. This condition may have been the result of local elevation which caused the mingling of meteoric waters with those of deeper origin. During the processes described there were migration and concentration of manganese and separation of manganese and iron. The alteration of the lava to greenstone was probably effected at the same time by the same or similar solutions, a conclusion that is perhaps supported by the fact that similar zeolites were deposited in both the ore and the country rock.

"5. After the above changes had been accomplished, tilting and faulting of the rocks by mountain-building movements, so that the manganiferous layer was exposed by erosion. Subsequent weathering is inconsiderable."

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[1] Pardee, J. T., op. cit. (Bull. 725-C), p. 236.

[2] Pardee, J. T., op. cit. (Bull. 795-A), pp. 13-16.

Still later, Hewitt and Pardee [1] concluded that "circulating hot waters related to igneous intrusions have either altered concentrated bodies of manganese carbonates or aided in the concentration of dispersed manganese carbonates. The resulting minerals are oxides, silicates, hydrous silicates, and carbonates of manganese."

Replacement probably plays an important part in the genesis of the ores, as has been indicated by Park [2] and Hodge.[3] All investigators have observed the significant association of basalt, jasper, manganese minerals, and red limestone. Further investigation may lead to modifications of present theories and throw additional light on the whole problem of origin.

BENEFICIATION

The deposits of the Olympic Peninsula are of special interest as a potential source of a vitally needed metal, provided an efficient and economical method of beneficiation can be developed. The continual and increasing demand of industry for pure metals is evidenced by the changing trend to electrolytic-metal production, and the large number of new alloys depend in great part on the purity of their component elements for their remarkable characteristics. Manganese plays an important role in this field, and the addition of manganese in the pure form, instead of as an alloy with its attendant impurities, would be most desirable.

The silica content of most of the manganese minerals of the peninsula is a component part of the ore, being in chemical combination; and therefore, conventional gravity or flotation methods will not serve to reduce the silica content. This is undoubtedly the principal reason why these deposits have lain dormant and why they have only lately attracted commercial attention. In recent years considerable research has been performed in an endeavor to find an economical method of treating the ores and making them of commercial value.

In 1934 the metallurgical division of the U. S. Bureau of Mines began to seek a practical solution of the problem of making industrially useful electrolytic manganese on an economically satisfactory basis, and a pilot plant was installed near Boulder Dam.[4]

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[1] Hewitt, D. F., and Pardee, J. T., Manganese in western hydrothermal ore deposits of the Western States (Lindgren volume), pp. 681, 682, Am. Inst. Min. Met. Eng., 1933.

[2] Park, C. F., Jr., Manganese deposits in the Olympic Peninsula, Washington (abstract): Econ. Geology vol. 34, pp. 944-945, 1939.

[3] Hodge, E. T., Preliminary report on some northwest manganese deposits, their possible exploration, and uses: War Dept. Corps of Eng., U. S. Army . . . North Pacific Div., Portland, Oregon, p. 41, 1938.

[4] Dean, R. S., Anderson, C. T., Moss, C., and Ambrose, P. M., Manganese and its alloys: U. S. Bur. Mines Rept. Inv. 3477, 47 pp. 1939.

Earlier work [1] showed that an electrolyte of manganese and ammonium sulphate could be used in a diaphragm cell, to produce a continuous deposit of high-purity manganese from water solutions during 48-hour periods, but the process had several practical limitations. Subsequent work, however, resulted in the successful production of electrolytic manganese from the Olympic deposits on a basis that appeared to be commercially feasible. The process was based on a reducing roast followed by leaching, using spent electrolyte plus additional sulphuric acid. The leaching solution was purified and then electrolyzed to produce manganese metal. Work was also carried on in the State Electrometallurgical Research Laboratories [2] at Pullman, Washington, under the direction of A. E. Drucker. This work consisted of adapting the leaching process to commercial practice, the elimination of some undesirable features, and the production of a suitable electrolyte on a continuous semi-pilot-plant scale. A proposed flow sheet based on the results of work performed is shown in figure 1. As a result of this research Drucker [3] states that, "We have, during the past years (1936 to October 1939) with the cooperation of the U. S. Bureau of Mines, solved this metallurgical problem for the production of high-purity electrolytic-manganese metal from the Olympic ores. The development of this process has made an entirely different story for the future use of these particular high-silica ores, which were of little or no use in making a suitable ferromanganese for the steel industry. These ores assay from 18 to 40 percent manganese, and would average better than 25 percent, for the production of 99.9+ percent electrolytic metal at from 7 to 9 cents per pound. They are of great future importance and are highly suited for this purpose."

For the past two years experimentation in the acid leaching of manganese ores has been carried on in the Chemistry and Chemical Engineering Department of the University of Washington under the direction of R. W. Moulton,[4] who says, "The results of our pilot-plant studies indicate that about 95 percent of the manganese present in the ore can be extracted by a combination sulphurous-sulphuric acid leach. We have tested ores from various localities in

[1] Shelton, S. M., Royer, M. B., Towne, A. P., Koster, J., Knickerbocker, R. G., and Doerner, H. A., Electrometallurgical investigations: U. S. Bur. Mines Rept. Inv. 3406, 22 pp., 1938.

[2] Sharp, F. H., The development of a sulphuric acid leaching process for the extraction of electrolytic manganese from certain high-silica ores of the Olympic Peninsula of Washington: Washington State College, Mining Exp. Sta. and State Electrometallurgical Research Labs. Bull. W-1, 1943. Schatz, R. W., Electrolytic manganese metal from the ores of the Olympic Peninsula, Washington: Washington State College, Mining Exp. Sta. Bull. W, 1939.

[3] Drucker, A. E., personal communication, Dec. 16, 1939.

[4] Moulton, R. W., personal communication, March 1944.

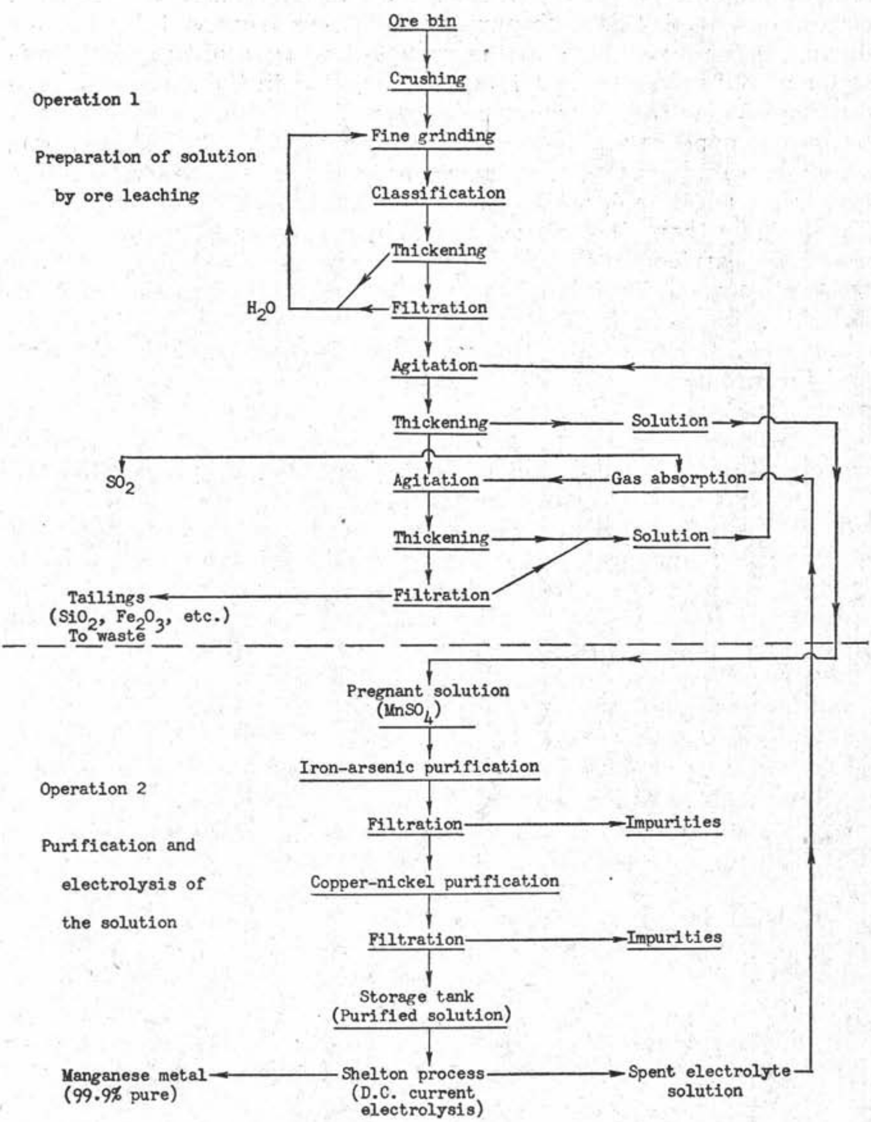

FIGURE 1.—Proposed flow sheet for electrolytic manganese.

this State and they all react similarly. The leach solution, which contains the extracted manganese in the form of manganous sulphate, is then the starting point for all manganese compounds. We have prepared manganese dioxide, manganese monoxide, metallic manganese by electrolysis, manganese sulphate, and manganese carbonate."

Two private companies have also been doing considerable work with ore from the Olympic Peninsula. Manganese Products, Inc., Seattle, built a pilot plant, and successfully made both manganese carbonate and manganese dioxide, also manganese-metal briquets. Experiments with the manganese dioxide in the construction of dry cells gave exceedingly satisfactory results. It is reported that this company is planning the erection of a commercial-sized plant. Olympic Mines, Inc., has constructed a commercial-sized plant at Hoodsport, Washington, and is reported to be producing, by the electrolytic process, approximately 400 pounds daily of metallic manganese, of 99.9+ percent purity. As soon as this company can secure some additional equipment, it is expected that the output will be materially increased. At the present time this plant is using ore from the State Lease deposit (see ref. No. 4) and from the Quinault area (see pp. 42-44), and expects to mine ore from the Elkhorn group (see ref. No. 34).

Two processes for the reduction of these high-silica ores by electrothermic methods, called the fusion and nonfusion methods, were worked on by Albert E. Greene, of the Greene Electric Furnace Co.[1] In one process the ore is heated in an electric furnace in an excess of finely divided carbon (coal). Both manganese and iron are reduced, the silica is not reduced, and the manganese is removed from the sintered mass as small metallic globules by mechanical means. In the second process, a molten bath of ferromanganese is provided, limestone is added to the ore for a flux, and as the temperature is raised, metallic globules of manganese separate out and sink in the molten bath. A slag containing silica, calcium, and excess carbon floats on the bath. Production of manganese can be made continuous by providing taps to withdraw the slag and the manganese. In large scale production, the ore-mix would be preheated by means of burning unconsumed gases in a preheating chamber. These experiments were on a small scale, hence not fully conclusive from a commercial standpoint. However, as a result of the work, Greene concluded that, "The recovery of a low-silicon ferromanganese by either the nonfusion or fusion method has been proved. The reduction of high-silica manganese ore by the low-temperature fusion method will recover the manganese in the form of a low-silica ferromanganese directly from the ore

[1] Greene, A. E., Report made for Civil Works Administration, June 1934.

* * * the carbon content of the metal can be kept below that of the usual alloy-furnace ferromanganese." It is clearly indicated that further work on these methods should be done, and their commercial possibilities conclusively proved.

U. S. GOVERNMENT PURCHASING SCHEDULE, 1942

The following outline of the Government's requirements, and methods used in purchasing manganese for stockpiling, are given in response to many inquiries for information on this matter:①

Specifications of grades purchased

	"High grade" percent	"Low grade A" percent	"Low grade B" percent
Manganese, minimum	48.0	44.0	40.0 *
Alumina, maximum	6.0	10.0	No maximum
Iron, maximum	7.0	10.0	No maximum
Phosphorous, maximum	0.18	0.30	0.50
Silica, maximum	10.0	15.0	No maximum
Zinc, maximum	1.0	1.0	1.0

* Under "Low grade B", manganese ore will be accepted to 35.0 percent minimum under penalties hereinafter prescribed.

Black oxide ores.—The schedule of prices and the terms and conditions herein refer to black oxide ores of manganese.②

Concentrates.—Manganese concentrates to be acceptable under this schedule must be nodulized or sintered.

Carbonate ores.—Manganese carbonate ore will be accepted under this schedule only if calcined.

Size of ore.—None in excess of 12 inches and not more than 25 percent to pass a 20-mesh screen.

Price.—Effective May 4, 1942, contracts will be considered on the following schedule for domestic ores, within continental United States (excluding Alaska); all prices per long ton (2,240 pounds) of dry weight, f.o.b. cars at stockpile designated by buyer.

"High grade".—Base price, $48.00 per dry long ton for ore containing 48.0 percent manganese, with an increase of one dollar ($1.00) per ton for each unit (22.4 pounds) in excess of 48.0 percent; fractions prorated. "High grade" ore containing not less than 48.0 percent manganese, but otherwise falling below specifications but with the limits hereinafter set forth, will be accepted subject to the following penalties:

Iron.—Up to 10 percent maximum with a penalty of 1¢ per unit of contained manganese for each percent of iron in excess of 7 percent; fractions prorated;

① Information concerning purchase of domestic manganese ores by Metals Reserve Company, Washington, D. C., from the schedule of May 4, 1942.

② Note that by this restriction the silicate ores of the Olympic Peninsula are not acceptable even though they may contain more than the minimum content of manganese.

Silica.—Up to 15 percent maximum with a penalty of 1¢ per unit of contained manganese for each percent of silica in excess of 10.0 percent; fractions prorated;

Alumina.—Up to 10 percent maximum with a penalty of 1¢ per unit of contained manganese for each percent of alumina in excess of 6 percent; fractions prorated;

Phosphorous.—Up to 0.30 percent maximum with a penalty of 1¢ per unit of contained manganese for each 0.03 percent of phosphorous in excess of 0.18 percent; fractions prorated;

"Low grade A".—Base price, $35.20 per dry long ton for ore containing 44.0 percent manganese, with an increase of eighty cents ($.80) per ton for each unit (22.4 pounds) in excess of 44.0 percent; fractions prorated;

"Low grade B".—Base price $26.00 per dry long ton for ore containing 40.0 percent manganese, with an increase of sixty-five cents ($.65) per ton for each unit (22.4 pounds) in excess of 40.0 percent; fractions prorated. Ore containing a minimum of 35.0 percent manganese will be accepted under this schedule with a penalty of $1.30 per ton for each unit (22.4 pounds) less than 40.0 percent; fractions prorated.

In addition to the above prices, an allowance will be made for each long ton shipped equal to the freight tariff per long ton from seller's nearest convenient rail station to buyer's stockpile.

ESTIMATION OF TONNAGE

Sufficient exploration has not yet been performed to estimate with any degree of accuracy the potential tonnage of the manganese deposits of the peninsula. Lateral extent is known in but few instances, widths are sometimes in doubt, and practically nothing is known about the depths to which deposits may extend. Exploration by diamond drilling or other means, and actual mining in one instance, have shown the lenticular nature of many deposits, whereby a pinching out of the ore occurs at depth. However, additional, deeper lenses may occur below those explored, as was proved in the Crescent mine (No. 19); or a given deposit may be sufficiently tabular or veinlike to maintain a minable width to considerable depth, as is reported from the Hurricane claim (No. 27).

Various estimates have been made of the potential tonnage, but until considerably more development and exploration work is completed, no worthwhile estimate is possible. The extent and persistence of the manganiferous zone certainly indicate the occurrence of a large and commercially important amount of ore.

DISTRIBUTION OF KNOWN OCCURRENCES

For the purpose of description, the manganese deposits are arbitrarily divided into those of the following areas: Pacific Ocean coast to Lake Crescent, Aurora Ridge, Storm King Mountain, Little River, Iron Mountain, Dosewallips River, Hamma Hamma River, North Fork Skokomish River, Steel Creek, and Quinault. To assist in locating the various prospects or occurrences on the area map (see pl. 1), the descriptions and numbers of these occurrences start at the extreme westerly end of the area and progress eastward, southward, and then westward.

CLALLAM COUNTY

PACIFIC OCEAN COAST TO LAKE CRESCENT VICINITY

Very little prospecting has so far been done between the ocean coast and the Hoko River, owing to the dense undergrowth and lack of trails. However, sufficient float ore has been found to indicate that the Metchosin rocks of that area contain deposits of manganese minerals as does the formation in better known areas to the east. Occasional occurrences have been noted between the Hoko River and Beaver Creek, but here again investigations have been scant. Eastward from Bear Creek, many manganiferous deposits are known and some have been thoroughly prospected.

1.—A considerable amount of float ore was found in westward-flowing tributaries of the Sooes River, a stream that flows into the Pacific Ocean just south of Bahobohosh Point, on Mukkaw Bay. Float has also been found in the hills adjacent to the upper reaches of the river.

2.—An occurrence of ore is reliably reported in the SE¼ sec. 27 (32-14W),[1] on a tributary of the south fork of the Sekiu River.

3.—Manganese ore occurs approximately 10 miles southwest of the Hoko River bridge, in sec. 10 (31-14W). The mineralization appears to be principally bementite, of good average grade. Cinnabar and some free mercury are present. The outcrop is 22 feet in length and 7 feet in average width.

4 *(State Lease)*.—The State Lease group of claims is about 2 miles northeast of Sappho, on Beaver Creek, near the center of the NW¼SE¼ sec. 16 (30-12W). This deposit has been exposed by trenching and sluicing, and by a short tunnel that cuts the ore about 10 feet below the floor of the trench. As exposed, the deposit is a massive lens having a length of 34 feet and an average width of 15 feet. The wall rocks are red limestone containing some concentrations of iron oxide. The limestone is overlain by sandy shale that crops out in the stream bed. In this deposit, hausmannite predominates and is accompanied by bementite and neotocite.

5.—Prospecting on the ridge extending from Beaver Creek to Bear Creek has disclosed several manganiferous deposits. Certain of these apparently contain some hausmannite and are in many respects similar to that on Beaver Creek. The Deep Creek forest fire in 1939 made a clean sweep of this ridge, and further prospecting should be done before the usual dense brush grows again, especially as the outcrops that can be seen give evidence of being high-grade ore.

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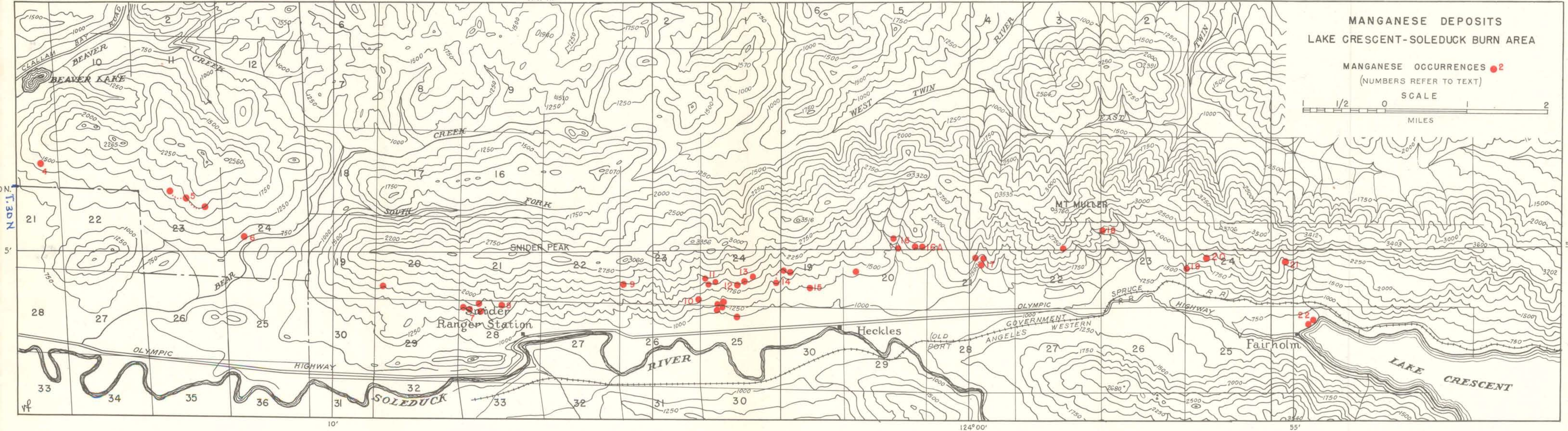
[1] Township 32 North, Range 14 West.

State of Washington
Department of Conservation and Development
Division of Mines and Mining
Sheldon L. Glover, Supervisor



6 *(Victory lode or Bear Creek deposit).*—The Victory or Bear Creek deposit is in the NW¼SW¼ sec. 24 (30-12W). The deposit, which is principally bementite, includes considerable neotocite and lies between two flows of basaltic breccia. When uncovered by stripping, the exposed width was increased from 1 to more than 6 feet in width. No limestone occurs with the deposit, although a large body of it was found above and about 300 feet toward the west. The contact between the deposit and the enclosing breccia is very irregular, and in places the ore is "frozen" to the wall rock.

Some 25 or 30 exposures of manganiferous deposits are known within the Soleduck Burn, which is on the south slope of the ridge that faces the Soleduck River, between Mount Muller and Snider Peak. Those found up to the present time occur in a belt between 1,500 and 2,500 feet in altitude, but other deposits may be outside these elevations.

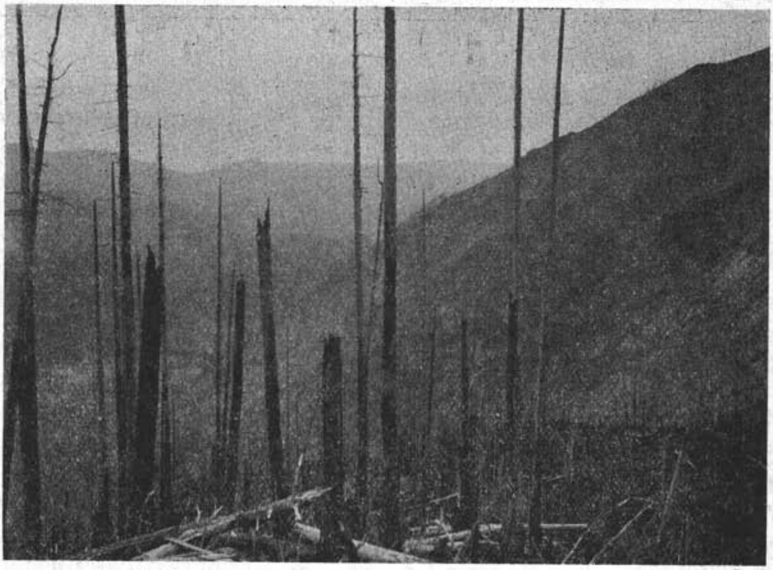
7 *(Clallam Nos. 1-2-3).*—In the NW¼NW¼ sec. 28 (30-11W), five trenches expose manganiferous bodies that are composed principally of bemenite. The first trench, at an altitude of 1,675 feet, exposes a lens having a length of 54 feet and an average width of 10 feet; the second trench, at an altitude of 1,615 feet, shows a lens 20 feet long and 4 feet wide; the third trench shows a body 26 feet long and averaging 5 feet in width; the fourth trench shows an outcrop having a length of 12 feet and a width of 3 feet; and the fifth one exposes an outcrop 26 feet long and averaging 5 feet 6 inches in width. All these occurrences lie between greenstone and red limestone. A pocket of cinnabar weighing about 2 pounds and lying between the deposit and the enclosing limestone wall rock was found while the second trench was being dug.

8 *(Seattle).*—A deposit of bementite 25 feet long and 12 feet wide, occurs in the SE¼ sec. 21 (30-11W), at an altitude of 1,845 feet. It is entirely surrounded by altered vesicular basalt.

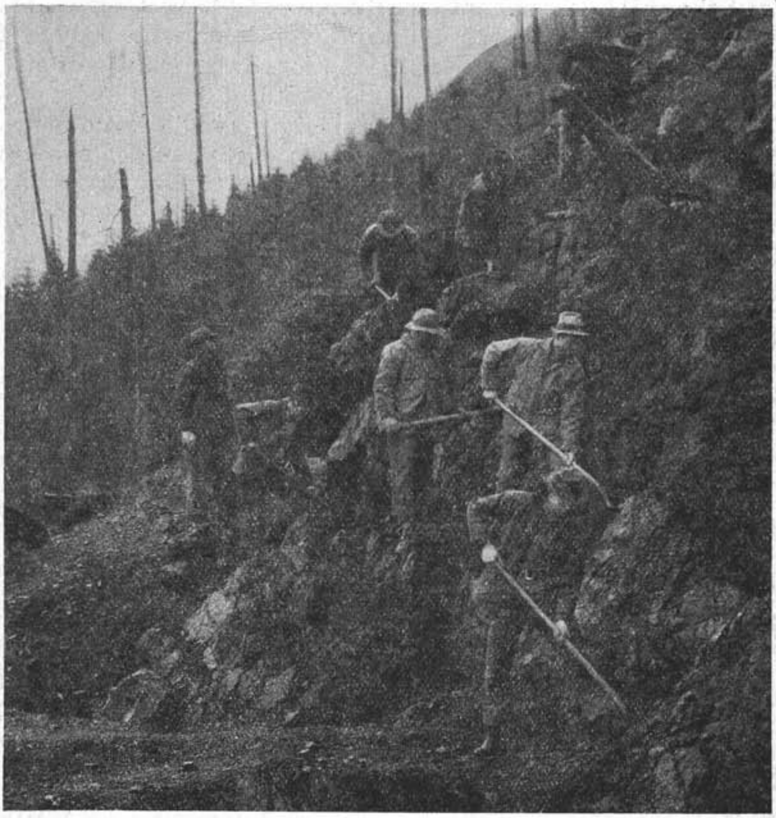
9 *(Barbara).*—In the SW¼ sec. 23 (30-11W), about 350 feet west of the Kloshe Nanich trail, at an altitude of 2,320 feet, are two deposits of bementite enclosed in greenstone. One is 20 feet long and averages 5 feet in width, and the other is 16 feet long and 5 feet wide.

10.—In the SE¼ sec. 23 (30-11W), at an altitude of 1,735 feet, another body of bementite surrounded by greenstone has been uncovered; it is 32 feet long and 8 feet wide.

11 *(Blue Eyes claim).*—In the N½SW¼ sec. 24 (30-11W), bementite and some neotocite are exposed in two trenches on the Blue Eyes claim, at an elevation of 2,260 feet. In trench No. 1 the lens has a length of 54 feet and an average width of 19 feet; in trench No. 2 it is 34 feet long and averages 8 feet in width. The deposit as exposed in these two trenches is very massive; it occurs in red



A. South slope of ridge between Mount Muller and Snider Peak, showing a part of the Soleduck Burn.



B. Crew stripping a deposit of manganese mineral. Works Progress Administration.

limestone and at a distance of 75 feet from an outcrop of basalt. Further exploration to determine its depth is warranted.

12 *(Pine Ridge claim).*—The Pine Ridge claim is in the SE¼ sec. 24 (30-11W), at an altitude of 2,135 feet. A trench exposes an outcrop of bementite that has a length of 62 feet and an average width of 24 feet 6 inches. About 75 feet below this trench a tunnel has been driven into the greenstone for 45 feet. No ore shows in the tunnel but the face of a short crosscut to the south is in ore.

13 *(Sunrise claim).*—In the SW¼NE¼ sec. 24 (30-11W), three distinct deposits of bementite are exposed by trenches on the Sunrise claim. The body in trench No. 1 is 50 feet 5 inches long and its average width is 4 feet; the one in trench No. 2 is 26 feet long and averages 3 feet in width; the one in trench No. 3 is 21 feet long and averages 4 feet in width. The outcrops stand vertically and strike N. 75° W.

14 *(Ed B group).*—The occurrences in parts of sec. 19 (30-10W) and sec. 24 (30-11W) are known locally as the Ed B group. In the NW¼ sec. 19 (30-10W), at an altitude of 1,825 feet is an ore body of bementite that showed, after stripping off the overburden, a length of slightly more than 260 feet and an average width of more than 25 feet. About 100 feet eastward, at an altitude of 1,765 feet, another body has been exposed having an area 64 feet in length and 35 feet in width. It is possible that these exposures represent one continuous body under the intervening 100 feet of overburden. Another deposit, 125 feet long and 82 feet wide, has been exposed by trenching and stripping; it lies between greenstone and red limestone east of Eureka Creek, in the SE¼ sec. 24 (30-11W), at an altitude of 1,545 feet. One distinctive feature of this last occurrence is that the red limestone accompanying it grades into limonite that has an exposed width of 15 feet. The limonite contains small masses of hematite.

15 *(June group).*—This deposit occurs in the SE¼SE¼ sec. 19 (30-10W); the altitude of the showing is only 1,265 feet, the lowest of any found on the Soleduck Burn up to the present time. It has been opened by a shaft, 16 feet deep and 13 by 9 feet in section, that shows ore on two walls as well as in the floor. The deposit is a vertical lens of bementite that strikes S. 76° E. and lies between basalt on the south and red limestone on the north; it is cut in a few places by veinlets of cinnabar. The basalt next to the ore is vesicular and contains calcite in veinlets and as fillings of vesicles; farther from the ore body it becomes more massive and finer-textured, and is heavily iron-stained.

16 *(Peacock* and *Johnnie M).*—On Littleton Creek in sec. 20 (30-10W), are two exposures of bementite. One of these, 14 feet long and 10 feet wide, lies about 100 feet east of the creek at an

altitude of 1,400 feet; the other, 9 feet long and 5 feet wide, is on the west bank of the creek at an altitude of 1,700 feet. Analyses of samples from these exposures show the bementite to be of medium-high grade and to contain some neotocite. Further exploration of this locality should be made.

(Littleton).—A third deposit is 500 feet west of Littleton Creek at an altitude of 1,400 feet; and a fourth, 10 feet long and 6 feet wide, is at the same altitude but 700 feet farther west on the west side of a small canyon.

16A *(St. Regis claims)*.—In the NE¼ sec. 20 (30-10W), the St. Regis claims are at an altitude of 1,985 feet. Two trenches expose deposits having lengths of 22 and 10 feet and widths of 12 and 6 feet, respectively. The bementite in these two trenches contains some veinlets of cinnabar.

17 *(Helen claim)*.—The Helen claim is near the center of the N½ sec. 21 (30-10W). There are two trenches. The first one, at an altitude of 1,905 feet, exposes a body of bementite 30 feet 4 inches long and 6 feet in average width. The other trench lies 476 feet toward the northwest, at an altitude of 1,965 feet, and shows a deposit 23 feet long and 6 feet in average width.

18 *(Sunshine)*.—In the NW¼NW¼ sec. 23 (30-10W), at an altitude of 2,340 feet, a body of bementite, approximately 24 feet long and 6 feet in average width and entirely surrounded by greenstone, crops out at the foot of a high cliff. Red limestone and argillite are exposed approximately 75 feet south of the exposure.

19 *(Crescent Mine)*.—The Crescent mine, located about 1 mile west of Lake Crescent, near the line between secs. 23 and 24 (30-10W), is the only deposit on the peninsula from which production of any considerable economic significance has so far been obtained. The deposit was discovered in 1923, at an altitude of 1,850 feet. Mining operations were started in 1924 by Jamison and Peacock under a lease from the owners, and during 1924, 1925, and 1926 a total of 16,275 tons were produced. The ore, predominantly hausmannite, was high grade; it contained an average of 53 percent manganese, 0.054 percent phosphorous pentoxide, between 7.78 and 8.93 percent silica, and between 0.74 and 1.13 percent iron oxide. Pardee[1] gives the following description of this ore body, upon which the first work was done: "The Crescent ore deposit is enclosed in badly crushed and sheared red limestone, which in turn gives place to sheared greenstone. In general the ore and country rock are definitely separated by walls that show evidences of fault movement. Locally there is a gradation between them, the wall rock being partly replaced by black manganese oxide (hausmannite) which brings out a nodular texture of the limestone.

[1] Pardee, J. T., op. cit. (Bull. 795-A), p. 17.

Commonly the wall rock contains thin white to pale pink veinlets of a zeolite (laumontite or thomsonite) and in one place material grading between limestone and ore shows seams coated with bright pink cinnabar. The unmixed wall rock contains a noteworthy amount of manganese. Unlike the porous, cavernous bodies in which manganese oxides produced by the weathering of carbonate lodes occur at Phillipsburg, Montana, and elsewhere, the Crescent deposit is hard, dense, and compact. Apparently it has withstood much of the deformation that has crushed and sheared the red limestone rock. Its colors are black and dull-reddish or pinkish shades of brown, and except for irregular joints and slip planes, it is structureless. The Crescent ore is a fine-grained intimate mixture composed chiefly of hausmannite (manganese oxide, Mn_3O_4), bementite (hydrated silicate of manganese, $8MnO.5H_2O.7SiO_2$), and a manganiferous carbonate. Hausmannite is the most abundant."

Jamison and Peacock suspended operations in 1926, partly because the ore proved to be a lenticular mass and had been practically exhausted, and partly because satisfactory arrangements for renewal of their lease could not be made with the owners. The property was subsequently sold to the Washington Manganese Corporation, who spent a considerable amount of money driving a low-level tunnel and several crosscuts in an endeavor to discover another ore body. In this they were unsuccessful and the property again reverted to the original owners. It lay idle until 1929, at which time the U. S. Bureau of Mines, in carrying out its strategic mineral investigation program, found a deeper body of hausmannite by diamond drilling. This was about 30 feet below the floor of the low-level tunnel, and occurred as a vertically elongated lens, from 6 to 28 feet thick, having a lateral length of 50-60 feet and a proven depth of 180 feet. Its strike was N.60°-70°W., and its dip nearly vertical. As was the case with the upper lens, the ore occurred in a red argillaceous limestone, in general about 20 feet from its contact with stratigraphically underlying basalt.

In 1941 the Sunshine Mining Company secured a lease, and in subsequent operations, still continuing in 1945, has produced more than 10,000 tons of ore from this lens. Present workings are at a depth of 950 feet below the outcrop. Recent drilling operations by the company have discovered another, still deeper, lens, which is reported to be as large as the one now being mined. This is of particular interest, as it not only shows that in this property ore extends to approximately 1,150 feet below the surface exposure, but indicates what may be expected at depth in other places where manganese lenses occur.

20 *(Peggy claim)*.—The Peggy claim is about 1,300 feet northeast of the portal of the present main Crescent tunnel, in the NW¼

sec. 24 (30-10W). On this claim a body of ore very similar to that of the Crescent mine has been uncovered, after a hole drilled by Jamison and Peacock cut ore 85 feet below the surface. The deposit appears to be one of considerable size, and analyses show that it consists predominately of hausmannite.

21 *(Daisy claims).*—Eastward from the Peggy claim are several occurrences on the Daisy claims, near the southwest corner of sec. 19 (30-9W). The outcrops, consisting principally of bementite, lie at an altitude of 2,100 feet. The exposures show an average thickness of about 6 feet, and they extend over a lateral distance of about 300 feet. It has not been demonstrated, however, that they are parts of a continuous ore body.

22 *(Daddy and Mother claims).*—Two outcrops occur 30 feet above the county road to Ovington. One is on the Daddy claim and one on the adjacent Mother claim. The common discovery post is 67 feet east and 7 feet north of the southwest corner of lot 4, sec. 30 (30-9W). They expose principally bementite with some hausmannite and are 4 to 6 feet thick, but sufficient trenching has not been done to show the length of the bodies.

AURORA RIDGE AREA

Aurora Ridge trends eastward between Aurora Peak and Lizard Head Peak, south of the eastern end of Lake Crescent. It rises from lake level to an altitude of more than 4,700 feet.

23.—Three manganese deposits occur on the north slope of the ridge at an altitude of approximately 4,200 feet. They are near the headwaters of the third south tributary of Barnes Creek, in what would probably be sec. 7 (29-8W), if the area were surveyed. One ore body, exposed for an estimated vertical distance of 175 feet on the face of a high bluff, has on top of the bluff a width of 50 feet and an exposed length of 125 feet. This deposit, while principally bementite, is notable for its high iron content.

24 *(Bertha claim).*—The Bertha claim lies just below the crest of Aurora Ridge about 1½ miles west of Lizard Head Peak. The main outcrop extends northwestward for about 50 feet, but in this distance it pinches from a maximum width of 40 feet down to 6 feet. The deposit, predominantly bementite, is distinctive for its high iron content.

For a distance of 1½ miles in an easterly direction small outcrops containing manganese minerals occur frequently on the north slope of Happy Lake Ridge, which is an easterly extension of Aurora Ridge.

STORM KING MOUNTAIN AREA

Outcrops containing manganese minerals are located on the north slope of Baldy Ridge, which extends from Storm King Mountain to Mount Baldy.

25 *(Thompson group)*.—The manganese occurrences of the Thompson group of claims are due south of the center of Lake Sutherland at an altitude of 3,400 feet, in what would probably be sec. 27 (30-8W), if surveyed. According to Park [1] lenses of manganese minerals have been found for 600 feet along the strike in a zone of tuff and limestone, which lies between basalt flows. They reach a maximum thickness of 5 feet but are generally less than 3 feet. The ore consists mostly of manganese silicate but contains some hausmannite.

LITTLE RIVER AREA

Several manganese deposits occur in the valley of the Little River, a tributary of the Elwha River.

26 *(Skookum claims)*.—The Skookum claims are about 4,000 feet northwest of the 6-mile post on the Little River trail, at an altitude of from 3,700 to 4,250 feet on a ridge that extends northward from Unicorn Peak. One deposit, at an altitude of 3,900 feet, is exposed in four open cuts, and shows a width of from 6 to 8 feet. It has been explored for 200 feet along the strike. A claim known as the upper Skookum is about N.75° W. from the openings described above, at an altitude of about 4,250 feet. The occurrence on this claim is a lens, about 8 feet wide, which lies between basalt and red limestone. Considerable float is in evidence between the Skookum and upper Skookum, but ore was not found in place. These outcrops show manganese silicates together with some hausmannite.

27 *(Hurricane claim)*.—The Hurricane claim is near Hutton Creek, a few hundred feet south of the Skookum, at an altitude of about 4,000 feet. A shaft, more than 45 feet deep, was recently sunk here, and approximately 1,000 tons of ore were taken out. It is reported that the bottom of the shaft is still in ore. The ore is said to be predominantly hausmannite and of high grade. About 300 feet eastward, at an altitude of 3,900 feet, another ore body is exposed.

Hutton Ridge is a westerly projecting spur from Mount Angeles, near the headwaters of Little River. A number of claims on outcrops of manganese minerals are located along this ridge.

28 *(Idaho, Broken Shovel,* and *Ella claims)*.—The Idaho, Broken Shovel, and Ella claims are on the crest of Hutton Ridge between

[1] Park, C. F. Jr., Manganese resources of the Olympic Peninsula, Washington: U. S. Geol. Survey Bull. 931-R, p. 447, 1942.

elevations of 4,200 and 4,720 feet. The outcrops occur intermittently for a distance of some 4,000 feet. On the western end of the ridge are cliffs that stand from 20 to 50 feet high, and in many places these are composed almost entirely of manganiferous material. The massive mineralized bodies range in length from 50 to 200 feet, and in width from 20 to 125 feet. The abundant and intimate association of jasper is a striking feature of these occurrences.

29 *(F and L claims)*.—The F and L claims are at altitudes of from 4,000 to 4,200 feet on a spur trending northward from Hutton Ridge. The manganiferous bodies, chiefly bementite, range from 6 to 43 feet in width and have been exposed by trenches for a distance of about 200 feet.

30 *(Chappie claims)*.—The Chappie claims, at an altitude of about 3,600 feet, are on the west side of the valley, on a spur connecting Hurricane Ridge and Unicorn Peak. These outcrops, composed predominantly of bementite, stand vertically and are exposed in the face of bold serrated cliffs ranging from 100 to 300 feet in height. The lodes vary from 2 to 5 feet in thickness.

31 *(J and J* and *Sunset claims)*.—The J and J and Sunset claims include several outcrops of manganese silicates that occur for approximately 2 miles along the south edge of Hells Canyon. Outcrops of manganese silicates are reported on the south slope of the third peak of Mt. Angeles.

JEFFERSON COUNTY

IRON MOUNTAIN AREA

Iron Mountain is at the headwaters of the Big Quilcene River near Copper Creek, a tributary of the Dungeness River.

32 *(Tubal Cain mine)*.—The Tubal Cain mine is on the northwest side of Iron Mountain, in sec. 7 (27-3W). The mine was originally opened in search of copper, and a tunnel, about 2,000 feet in length, was driven at an altitude of 4,400 feet. Approximately half a mile northwest of this tunnel another copper prospect called Tull City was opened. Between these two mines, and extending southward, a craggy ridge reaches an altitude of about 6,900 feet. Just east of the crest of this ridge, on the face of a steep bluff, manganese ore crops out, and a considerable tonnage of it is found in talus at the foot of the bluff. The mineral is exposed in tabular bodies that form almost a continuous lode. In reference to this occurrence Patty [1] quotes an unpublished report of Henry Landes, made in 1918, as follows:

"The Tubal Cain deposit is situated above timber line, the outcrops attaining a maximum elevation of 6,300 feet, so that the ex-

[1] Patty, E. N., The metal mines of Washington: Wash. Geol. Survey Bull. 23, p. 318, 1921.

posures are exceptionally good. The lenses of brown silicate are developed in a red limestone, and they form practically a continuous lode at least 1,500 feet long and 6 feet in average width. The natural cross-sections show that the lode persists to a depth of at least 500 feet. It is conservatively estimated that this body of ore contains 450,000 tons of ore."

According to Park, [1] "The ore body, consisting principally of manganese silicates, is tabular; it is about 300 feet long, and its width attains a maximum of 8 feet but probably averages between 1 and 2 feet. * * * Southward, small scattered and irregular lenses of ore-bearing limestone continue."

DOSEWALLIPS RIVER AREA

33 *(Lucky Creek claim).*—An outcrop of ore occurs in sec. 25 (26-3W), at an altitude of 1,500 feet in the east wall of the narrow canyon of Lucky Creek. The exposure is tabular; it is composed predominantly of bementite containing some neotocite, and is continuous for about 500 feet, varying in width from 2 to 3 feet. It lies between basalt on the east and tuff on the west. This deposit, though narrow, is notable for its uninterrupted length. Intermittent outcrops appear on about the same strike for a considerable distance to the south.

34 *(Elkhorn group).*—About 6 miles up the Dosewallips River from Lucky Creek is the Elkhorn group of claims, near Miners Creek, in secs. 13 and 24 (26-4W). These claims lie between altitudes of 1,000 and 5,700 feet, and the manganiferous outcrops are exposed intermittently up the mountain side. The general rock of the area is basalt; interbedded with this are three distinct limestone beds that trend approximately north, and stand almost vertical, although locally showing marked variation from this attitude. They are called the east, west, and middle beds, and enclose the manganese ore. The bodies exposed have known thicknesses of as much as 25 feet, and are thought to be discontinuous lenses, but sufficient development or prospecting has not yet been done to definitely establish this fact. It is known, however, that a large number of ore bodies occur on these claims and that the mineralization is predominantly bementite. The Olympic Mines Inc. has recently taken a lease on this property and is planning on mining the ore for its plant at Hoodsport.

35 *(Mount Claywood)*[2].—Altered volcanic rocks, commonly ellipsoidal, occur at various places well within the area that is

[1] Park, C. F., Jr., The manganese resources of the Olympic Peninsula: U. S. Geol. Survey Bull. 931-R, p. 451, 1942.

[2] Glover, S. L., from field studies made in 1934 during a regional investigation for the State Division of Geology, the results of which are unpublished. Petrographic and polished-section analyses by W. A. G. Bennett, Division of Mines and Mining.

partly surrounded by the prominent belt of Metchosin volcanic rocks. They compose a considerable part of Mount Claywood, in sec. 30 (27-5W), and occur in Sentinel Peak, both at the headwaters of the Dosewallips River; they are present in Mount Deception, in sec. 30 (27-4W), and in an easterly spur of Diamond Mountain in sec. 15 (26-5W), respectively north and south of the Dosewallips River; and they are indicated as occurring in the ridge between the Quinault River and Rustler Creek by angular boulders in a small stream between Pyrites and No Name Creeks. These, and probably other occurrences yet to be recognized, appear to be erosional remnants or outliers of the Metchosin volcanics. It is reasonable to presume that the Metchosin series originally covered what is now the central portion of the peninsula area, and that in certain places the flows and associated sedimentary rocks escaped erosion by being infolded or down faulted into the older, underlying sedimentary series; the field evidence appears to bear this out.

Manganese mineralization would be expected in these areas, particularly if limestone were present, but the Mount Claywood occurrence is the only one that is known, and here the mineralization is a peculiar iron-manganese combination that is probably manganmagnetite. This exposure is on the steep east side of the mountain above and in line with the ridge forming the divide between the Dosewallips and Lost Rivers. It is of interest because relationships are so well displayed in shallow gullies where nearly all loose rock and cover have been swept from the steeply sloping bedrock. In most instances, here, the iron-manganese material is in distinct layers or lenses conformable to associated limestone, but it also occurs as isolated irregular lenses in the greenstone and as veinlike or dikelike masses cutting through the greenstone. One such vein ends in a pillow of greenstone that is nearly completely replaced by the iron-manganese mineral.

A general stratigraphic section was in part measured and in part roughly estimated.

Section from east side of Mount Claywood

	Ft.	in.
Top of mountain, altitude 6,828 feet		
Quartzite and slaty argillite	200+	
Greenstone, containing at least one irregular curved lens of iron-manganese material[1] approx.	300	
Brown limestone, containing a very irregular mass of iron-manganese as much as 20 feet in thickness approx.	30	
Thin-bedded greenish-gray limestone approx.	20	
Quartzite, limestone, and thick beds of greenstone	?	
Brown limestone and iron-manganese in large contorted masses	?	
Greenstone; remarkable development of pillow structure, prominent joints coated and filled with manganese minerals, cut by quartz and calcite veinlets	100	
Iron-manganese	1	
Limestone		5
Iron-manganese and limestone		3
Limestone and some iron-manganese		10
Iron-manganese		6
Limestone and stringers of iron-manganese		4
Iron-manganese and thin layers of limestone		3
Limestone and stringers of iron-manganese		8
Iron-manganese and limestone in variable amounts	1	7
Limestone and stringers of iron-manganese		10
Iron-manganese and some limestone		8
Limestone, dark-gray, weathers red-brown; altitude approximately 6,100 feet	7	
Massive quartzite underlain by interbedded quartzite, thinbedded limestone, argillaceous limestone, and nearly black slaty argillite		
	682+	

[1] For convenience, similar material is referred to hereafter in this section as "iron-manganese."

This iron-manganese mineral or, more properly, mineral aggregate has not been described previously, despite the fact that it may be rather common in the manganese occurrences of the peninsula. Aside from the outstanding examples on Mount Claywood, occurrences are known near Lena Lake (No. 37) and on Copper Creek (No. 38). In the outcrop, the material appears homogeneous and very similar to the manganese mineralization of other places in the peninsula; in fact, it is easily confused with the usual black, surface-oxidized bementite.

The material is dark gray to grayish black, has a black to greenish-black streak, is brittle, fine grained, and strongly magnetic. The apparent hardness is 6 and the apparent specific gravity, 3.34. The fracture is uneven, though masses may split easily in several directions, commonly forming rather smooth-sided rhomboidal fragments, a feature that is probably due to fine-scale jointing.

Internal structure is obscure except on polished surfaces, then a distinct minute banding is obvious. The bands are composed of a hard gray metallic mineral having a black streak, tentatively identified as manganmagnetite ($FeO.Fe_2O_3.nMnO$). This occurs in very fine interlacing veinlets enclosing ovoid bodies and as minute lenses; also as finely disseminated grains between the more prominent bands, and as aborescent or tuberous growths that appear to extend inward from fracture planes. Between the principal metallic masses is a yellowish-green cryptocrystalline material containing numerous similarly colored ovoid bodies from 1 to 2 millimeters in diameter that are mostly elongated as well as arranged parallel to the banding. Many of these bodies contain a nucleus of calcite. Narrow veinlets, mostly of calcite but also of the yellowish-green material, are common and cut the banding. Some of the manganmagnetite appears to have been introduced later than that which forms the banding but earlier than the calcite veinlets.

The yellowish-green (chloritic?) groundmass as well as the ovoid bodies have low birefringence and an index of refraction of about 1.64; it contains considerable sericitic mica and occasional plates of a reddish-brown, probably manganiferous, mineral whose maximum index of refraction is about 1.715. One mount of powdered fragments showed a single grain that was probably glaucophane. A chemical analysis of the material by Willis H. Ott shows silica (SiO_2) 14.1 percent, iron (Fe) 27.7 percent, calcium oxide (CaO) 16.2 percent, and manganese (Mn) 7.72 percent. A spectrographic analysis by E. W. Miller gave iron, calcium, and manganese in concentrations over 10 percent; silicon, between 10 and 1 percent; aluminum, magnesium, and titanium, between 1 and 0.1 percent; sodium, tin, chromium, vanadium, strontium, nickel, and boron between 0.1 and 0.01 percent; molybdenum, copper, gold, zinc, and cobalt, between 0.01 and 0.001 percent; and barium below 0.001 percent.

36.—On the Duckabush River in secs. 4 and 5 (25-3W), manganiferous outcrops are reliably reported on the flanks of both Big and Little Hump Mountains.

37 *(North Pole Quartz and Black Hump claims)*[1].—Near Lena Lake, in the NE¼ sec. 35 (25-4W), the North Pole Quartz claim was staked many years ago at an altitude of about 3,200 feet on several occurrences of manganese-bearing mineral. One outcrop is 6 feet long and 4 feet wide, a second is 8 feet long and 5 feet wide; each of these has associated jasper and hematite and is enclosed in greenstone. No limestone crops out. Other masses, less well exposed, are nearby, projecting through the scant soil cover of the steep mountain side. The mineral is high in iron and apparently

[1] Glover, S. L., personal communication. 1944.

very similar to the "iron-manganese" material of Mount Claywood (see No. 35).

Other claims were staked farther to the north on the ridge between East Fork Lena Creek and Cabin Creek; one, the Black Hump, in the SW¼ sec. 19 (25-3W), altitude about 4,500 feet, has exposures of hematite in greenstone but shows very little that indicates the presence of appreciable amounts of manganese.

MASON COUNTY

NORTH FORK SKOKOMISH RIVER AREA

Several occurrences of manganese minerals are on the tributaries of the North Fork Skokomish River northwest of Lake Cushman.

38 *(Triple Trip deposit)*.—The Triple Trip (Brown Mule) deposit is in secs. 4 and 9 (23-5W), about one-quarter mile up Copper Creek from its confluence with the Skokomish River. An elongated lens of ore, having a length of 50 feet and a width varying from 1 to 4 feet, is uncovered along a basalt-red limestone contact. Tunnel No. 1, planned as a working entry, failed to find ore, although it was driven only 35 feet below the discovery outcrop of the lens. Tunnel No. 2, driven as a crosscut about 60 feet southwest of No. 1, reached the ore of the 50-foot lens, but at only 25 feet or so below the surface exposure.

The ore, while predominantly bementite, has associated with it some oxides, and in places has phases similar to the "iron-manganese" material of the Mount Claywood occurrence (see No. 35). Minor amounts of jasper are present in some places. Up the creek, to the southwest, other small masses of ore have been uncovered in pits on the strike of the lower lens for a distance of a thousand feet or more, but the existence of a continuous body has not been demonstrated. According to Pardee,[1] the analyses of six samples, said to be representative of the lower lens, show from 6 to 25 percent manganese, 8 to 21 percent iron, 11 to 37 percent silica, and 4 to 36 percent lime. It is reported that during World War I a carload of ore was shipped from this property, 15 tons being from a small stope in tunnel No. 2.

39 *(Apex mine)*.—The Apex mine, about half a mile up Copper Creek from the Triple Trip, at an altitude of 2,400 feet, has a large showing of manganese ore. During 1940 the U. S. Bureau of Mines stripped this occurrence and did some diamond drilling. Park[2] reports that this exploration showed the deposit to be about 25 feet in maximum width, to have an explored length of at least 250 feet, and to "continue to some depth with about the same size and grade that it had on the surface." The mineralization consists of

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① Pardee, J. T., op. cit. (Bull. 724-C), p. 237.

② Park, C. F., Jr., op. cit. (Bull. 931-R), p. 456.

manganese silicates, oxides, and carbonates together with much jasper. The deposit trends N.70°-75° E., parallel to Copper Creek, and lies between nearly vertical beds of greenstone and red limestone, apparently a continuation of the same zone of limestone and greenstone as that of the Triple Trip. A sample taken by Pardee from a 6-foot section across the lode contained 43.10 percent manganese oxide, 12.65 percent iron oxide, 3.87 percent lime, and 19.81 silica.[1]

40 (*Black Queen* and *Hi Hope claims*).—A group of six claims known as the Black Queen Nos. 1-6 are in sec. 4 (23-5W), a quarter mile or so up the west side of the Skokomish River from Copper Creek and the Triple Trip deposit. They have been explored by several open cuts and a shallow shaft. In one open cut a mass of manganese silicate and jasper strikes N.50°E. and dips 75°NW. It has a width of from 2 to 3 feet and length of about 20 feet. The mineralization is at the contact of greenstone and red calcareous argillite. The shaft, evidently sunk many years ago, showed no ore. Other manganese bodies probably occur in the vicinity, but prospecting is rendered difficult by the overburden and brush.

The Hi Hope claims are on the east side of the Skokomish River on about the projected strike of the Black Queen manganese occurrence. A 50-foot adit, driven on a greenstone-red argillite contact, was partly caved in 1942 and could not be entered. Several pieces of bementite float are in the soil above the adit, and one mass, possibly in place, has a width of about 2 feet.

41 (*Black and White mine*).—The Black and White mine is about 5 miles north of the Triple Trip property, on the divide east of the North Fork Skokomish River, in sec. 17 (24-6W). Park[2] reports that it was orignally staked (as the Three Friends claim) for copper in 1907, and a shipment of about 5 tons to the Tacoma Smelter in 1915 contained 0.40 ounces of silver per ton, 7.85 percent copper, 3.2 percent iron, and 65 percent insoluble material. The presence of manganese was not recognized until 1918, and at about that time approximately 100 tons were shipped to the Bilrowe Alloys Company, Tacoma, for experimental purposes. The mine is in a small cirque at an altitude of 4,400 feet, where the country rock consists of alternate beds of greenstone, argillite, and graywacke. The mineralized zone follows the contact between sedimentary and igneous rocks. None of the usual red limestone crops out near the deposit but occurrences are known in the vicinity. Development work consists of a 200-foot tunnel at an altitude of 4,300 feet, a 40-foot shaft above the tunnel but not connected with it, and several pits and open cuts for 300 feet along the strike of the lode.

[1] Pardee, J. T., op cit. (Bull. 725-C), p. 238.

[2] Park, C. F., Jr., op. cit. (Bull. 931-R), pp. 453, 454.

Exposures are poor, but one lens in the lode as exposed at the shaft has a width of 8 feet; marked pinching and swelling, both laterally and at depth, are features of the mineralization. The ore is principally bementite, with which are associated minor amounts of neotocite and manganese carbonates and oxides. Native copper is present as minute flakes, granules, and irregular masses as much as one-quarter inch across; some sulphides occur; and copper carbonates and silicates form a surface stain in parts of the exposure. An average sample taken across the 8-foot lode is given by Pardee [1] as containing 29.63 percent manganese oxide, 12.38 percent iron oxide, 0.706 percent lime, and 24.35 percent silica.

About 750 feet northwest of the Black and White property is a claim known as the Arkansas Traveler, on which is a small showing of manganese mineral.

42 *(Smith mine)*.—Claims originally staked in 1914 are in sec. 22 (24-5W), a mile southeast of the Black and White. No information is available on what the mineralization is at this place.

42A.—Many claims have been staked up the Skokomish River for 7 or 8 miles above the head of Lake Cushman, and various small amounts of development work have been done. Old maps show the "Darky mine" to be at the mouth of Nine Stream in sec. 6 (24-5W); this could not be found, although a 1-foot quartz vein carrying sparse sulphides without manganese mineralization crops out across the Skokomish River from this place and has had some work done on it. A property known as the Smith Keller or Lucky Wednesday mine is near the mouth of Seven Stream, in sec. 18 (24-5W). In 1934 it was being worked by Negroes; so probably this is the "Darky mine," and the section location as given on the maps is in error. The only apparent mineralization is a sparse dissemination of pyrite in argillite near a greenstone contact. Reported occurrences of bementite could not be verified.

STEEL CREEK AREA

43.—In sec. 10 (23-6W), on Steel Creek, a tributary of the South Fork of the Skokomish River, there are several claims on the south slope of Wonder Mountain, at altitudes of from 2,000 to 3,500 feet. The outcrops are very similar to those of the bementite bodies along the North Fork of the Skokomish River. Pardee [2] states, "On the Bosnia claim, a short distance above the Steel Creek cabin, there is an outcrop of bementite rock similar in appearance to the outcrops of the Triple Trip and Apex. It is 8 or 10 feet wide, at least 200 feet long, 100 feet in vertical extent, strikes about N.75°E., dips 75°S., and is enclosed by red limestone. In a gully 200 feet to the east is another exposure 10 feet wide, of which 6 feet is red jaspery quartz

① Pardee, J. T., op. cit. (Bull. 725-C), p. 240.
② Pardee, J. T., op. cit. (Bull. 725-C), p. 241.

and the remainder bementite rock. Half a mile farther on, within the limits of the India claim, is a prominent outcrop of bementite rock 15 feet wide and 50 feet long. It is associated with red jasper and red limestone and is otherwise similar to the bementite bodies in general. Several other outcrops of comparable size are reported to occur within a mile or so farther east. Abundant float fragments of bementite rock were observed in gulches leading from the area down to the South Fork, and cobbles of bementite rock easily recognized by their black color and weight—they are heavier than the same sized cobbles of ordinary rocks—are common along the main stream. * * * The exposures indicate that the bementite bodies are extensive. Some specimens obtained contain primary oxides like those occurring in the bodies on the North Fork, and the development of the South Fork deposits may be expected to disclose more or less mixed bementites and oxide ore capable of being reduced in an electric furnace."

Park,[1] in writing of these same occurrences, speaks of them as "several small lenses in siliceous red limestone near its contact with basalt. These lenses lie parallel to the bedding, which strikes nearly east and dips 35°-50°S., forming a dip slope on the south side of the mountain. As the ore bodies thus lie flat on the hillside, they give an exaggerated impression of the quantity of ore they contain. The three principal lenses, which lie at altitudes of 2,600 to 2,900 feet, apparently contain in all about 1,000 tons of manganese silicates."

GRAYS HARBOR COUNTY

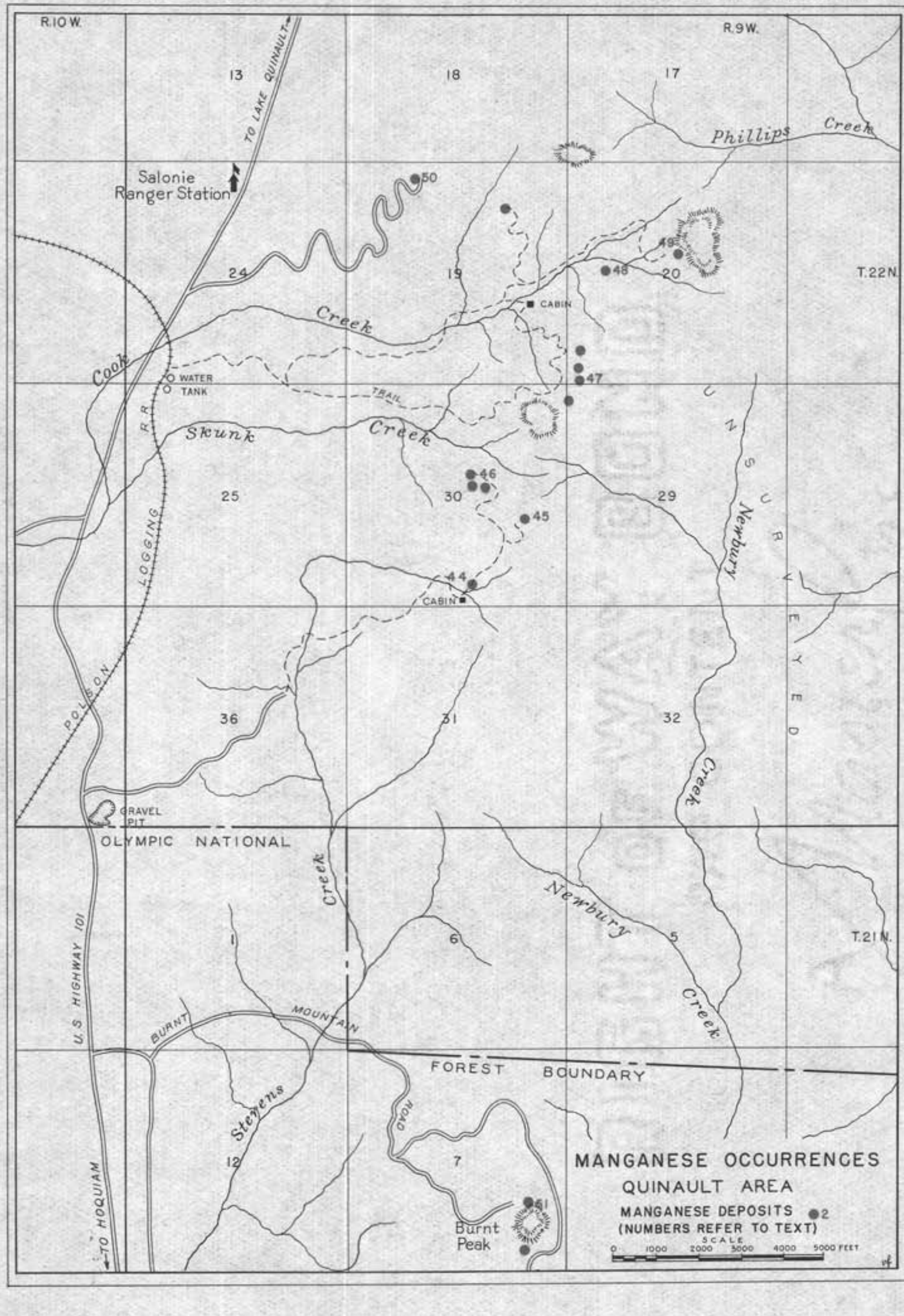
QUINAULT AREA

More than 20 occurrences of manganese minerals are known in this area. They occur in a belt approximately 2 miles wide and 8 miles long, lying east of the Olympic Highway, in T. 21 and 22 N., R. 9 W., at altitudes ranging from 790 to 1,500 feet. This is in a low range of wooded, brush-covered hills that extends southwestward between the drainage of the Quinault River on the west and the Humptulips River on the east. In the vicinity of the deposits, Cook, Skunk, and Stevens Creeks have cut deep but narrow valleys. Cook and Skunk Creeks flow westward to the Quinault River, and Stevens Creek flows southward to the Humptulips River. In general, the deposits occur near the crest of the ridges, and are associated with greenstone, and usually with a red calcareous argillite and limestone. One distinctive feature of the mineralization in this area is the advanced oxidation, whereby the bementite is altered not only on the surface and along joints and seams, but also to an appreciable depth in apparently massive mineral. Several of the occurrences can be reached by short trails from the main highway, and a mine-to-market road up Cook Creek was completed in 1943.

[1] Park, C. F., Jr., op. cit. (Bull. 931-R), pp. 456, 457.

State of Washington
Department of Conservation and Development
Division of Mines and Mining
Sheldon L. Glover, Supervisor

Report of Investigations 7 Plate 5



44.—Two parallel deposits occur on Stevens Creek in the SE¼ sec. 30 (22-9W), at an altitude of 790 feet. One of these has a width of 6 feet and can be traced for approximately 40 feet; the other has a width of 9 feet and is exposed for 15 feet to where it passes under a greenstone outcrop. The predominant mineral is bementite, but some neotocite and possibly rhodonite occur in small veinlets; the ore shows considerable surficial oxides. Red calcareous argillite occurs in beds between the ore exposures and to the east of them, but greenstone apparently forms the walls of both deposits.

45.—Several large boulders of bementite are about 1,500 feet up the North fork of Stevens Creek from No. 44, at an altitude of 1,150 feet. A 12-foot tunnel has been driven here in greenstone but shows no manganese minerals. A large body of red calcareous argillite is nearby.

46 *(Star)*.—The old Star claims are near the center of sec. 30 (22-9W), at altitudes of 1,300 to 1,470 feet. The ore bodies have the appearance of being isolated masses or lenses; one is 6 feet wide and 10 feet long and is enclosed in red calcereous argillite, two others are 7 by 9 feet, and 5 by 9 feet, respectively, and are in contact with greenstone and dark-red limestone. The principal mineral is bementite and its oxidation products.

47.—On the north side of the divide between Skunk and Cook Creeks, in the SW¼SW¼ sec. 20 (22-9W), a deposit is in contact with greenstone a short distance above an outcrop of red limestone. A small tunnel, now covered, evidently intersected the ore, as pieces of it were found on the dump. The ore is mostly bementite and is associated with some jasper. Approximately 600 feet northeastward another small outcrop is exposed at the base of the same greenstone bluff.

48.—An outcrop of bementite surrounded by greenstone lies on the south side of Cook Creek at an altitude of 1,170 feet in the NW¼ SW¼ sec. 20 (22-9W). It is small and appears to be of much lower grade than the average for the area, owing to the abundance of associated jasper.

49.—In the NE¼SW¼ sec. 20 (22-9W), at an altitude of 1,250 feet, a deposit has been explored by a tunnel 10 feet long. Some 2 tons of ore, consisting principally of bementite but including considerable jasper, are on the dump. The ore could not be found on the walls or face of the tunnel, and the floor was concealed by caved material.

50 *(Esther-Irene)*.—An outcrop of bementite and the usual accompanying oxides occurs on the Esther-Irene claim, in the NW¼ sec. 19 (22-9W), at an altitude of 1,265 feet. It has been exposed by stripping in three places within a distance of 100 feet and by

an open cut 35 feet farther west. The walls are red argillite and greenstone. The occurrence has the appearance of being relatively large, but more stripping is necessary to show its actual extent. The owners report having assays running as high as 40 percent in manganese. There are about 75 tons of hand-sorted ore in the bunker, and some has been shipped. The property is connected with the Olympic Highway by a mine-to-market road.

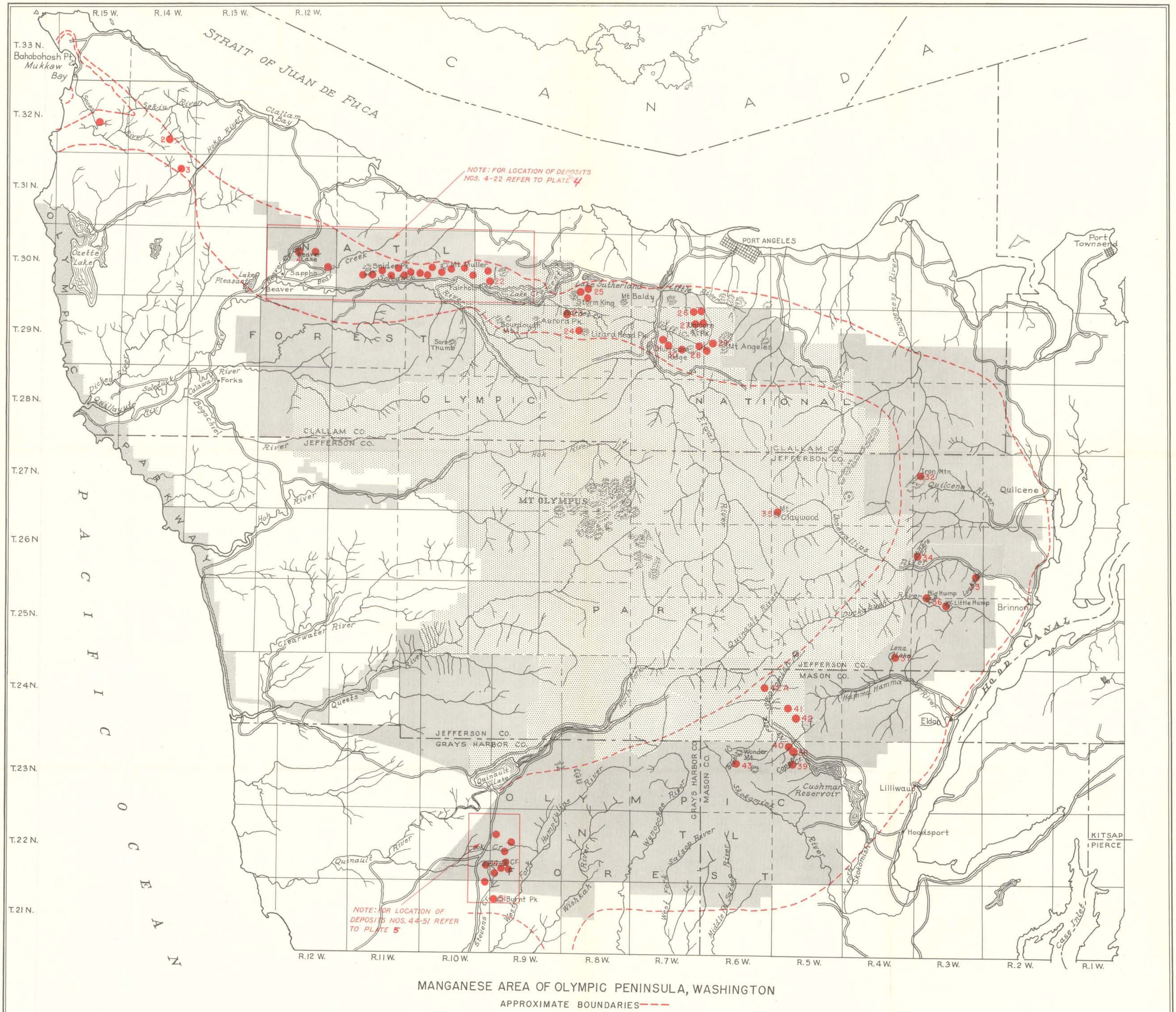
51.—Manganese minerals are exposed at several places on Burnt Peak, in the SE¼ sec. 7 (21-9W). On the northwest side of the peak, at an altitude of 818 feet, a 220-foot tunnel on the north side of a small gulley shows manganese ore in the west wall. For 200 feet westward, trenching has exposed small isolated masses of ore. South of the tunnel, for a distance of 50 feet, the mineralization can be traced to an open cut in the south side of the gulley. Approximately 600 feet farther south are two open cuts and a short tunnel, all of which show manganiferous bodies. These last are on a continuation of the strike of those in the gulley, but it is very doubtful that they are connected. However, from the exposures that can be seen it is believed a considerable tonnage of ore is available in this locality. The mineralization is bementite together with considerable surficial oxide. The associated rocks are greenstone and red limy argillite. A road leads to the deposits and makes them easily accessible. Approximately 80 tons of ore have been mined and shipped.

Analyses of samples from manganese occurrences on the Olympic Peninsula

[Dr. Irwin A. Pearl, University of Washington, analyst]

Reference no. ①	Sample no.	Mn	Fe	SiO_2	Reference no. ①	Sample no.	Mn	Fe	SiO_2
4	1	41.84	3.21	13.68	13	11	20.62	19.42	29.98
7	1	15.70	29.69	25.51	13	12	17.72	17.52	35.24
7	2	13.71	18.50	41.51	13	13	21.19	22.61	27.30
7	3	30.92	17.79	23.51	13	14	26.73	20.27	22.28
7	4	20.88	22.17	29.01	13	15	20.83	19.50	35.17
7	5	21.25	21.85	29.59	13	16	18.94	18.42	27.69
7	6	21.96	20.00	30.00	13	17	17.33	21.60	28.40
7	7	17.40	26.28	23.97	13	18	20.33	15.98	36.41
7	8	22.77	21.51	29.95	13	19	25.57	13.87	29.06
7	9	5.57	27.32	29.08	13	20	24.57	12.76	32.88
7	10	20.16	19.05	32.38	13	21	16.59	21.18	30.14
7	11	23.35	13.22	32.01	13	22	19.61	13.54	31.17
7	12	28.17	8.90	35.12	13	23	18.07	22.78	28.85
7	13	17.55	10.69	58.54	13	24	17.66	20.87	33.45
7	14	24.77	16.92	27.39	14	1	26.91	11.40	23.18
7	15	23.54	16.49	28.28	14	2	22.18	14.13	25.88
7	16	22.68	14.44	28.95	14	3	27.48	17.34	20.56
7	17	24.66	16.01	29.94	14	4	23.80	16.52	26.79
7	18	23.35	19.90	19.90	14	5	19.72	19.18	32.47
7	19	18.51	19.74	46.72	14	6	33.00	13.00	20.23
7	20	21.19	14.40	36.59	14	7	24.52	18.95	19.89
7	21	19.02	14.95	37.75	14	8	24.02	14.57	24.28
7	22	24.74	16.62	30.07	14	9	17.01	22.84	28.25
8	1	14.65	20.48	46.12	14	10	23.23	22.00	55.94
8	2	18.85	23.20	37.94	14	11	13.63	24.50	34.84
8	3	15.73	23.76	34.73	14	12	31.37	18.12	12.75
8	4	32.22	15.63	17.17	14	13	16.76	32.84	21.21
8	5	32.49	16.06	16.59	14	14	25.82	22.86	23.27
9	1	16.51	17.87	34.60	14	15	14.44	34.66	22.38
9	2	19.64	14.63	44.85	15	1	14.98	23.61	30.99
9	3	39.80	19.11	37.92	15	2	16.75	23.16	27.42
9	4	28.63	21.75	40.76	15	3	18.18	19.34	26.78
9	5	27.32	13.07	38.13	16	1	33.20	7.17	23.86
9	6	30.85	12.56	30.01	16	2	33.08	7.42	25.54
9	7	19.77	11.69	31.59	17	1	34.80	14.32	17.73
9	8	30.00	14.09	31.47	17	2	34.50	6.62	17.22
12	1	24.46	18.62	24.95	17	3	32.20	19.47	13.54
12	2	20.17	33.15	18.33	17	4	32.60	9.61	25.88
12	3	22.11	26.67	21.98	17	5	40.74	8.56	9.07
12	4	25.69	19.82	26.33	17	6	26.38	7.45	32.40
12	5	12.33	11.92	60.65	17	7	27.02	8.59	30.04
12	6	23.39	22.57	23.24	17	8	36.25	6.78	29.09
12	7	19.46	20.94	32.25	19	1	51.50	1.30	13.70
12	8	22.81	20.68	30.27	20	1	45.90	8.21	17.06
13	1	28.19	15.73	18.36	22	1	30.60	4.60	26.50
13	2	19.68	20.67	25.44	25	1	34.20	9.20	19.20
13	3	4.64	17.01	63.93	25	2	30.60	6.20	34.20
13	4	10.43	34.85	28.90	28	1	13.84	13.02	53.59
13	5	13.93	15.93	46.77	28	2	25.06	12.14	50.85
13	6	16.73	26.36	30.90	29	1	9.92	13.48	63.88
13	7	12.20	21.12	49.51	29	2	25.80	15.20	34.10
13	8	29.85	16.90	18.63	29	3	21.60	9.28	50.75
13	9	24.01	17.70	24.15	29	4	10.81	9.38	65.63
13	10	25.18	14.36	26.30	29	5	12.21	16.58	47.23

① The reference numbers correspond to numbers as shown on pages 36 to 45 of text.



MANGANESE AREA OF OLYMPIC PENINSULA, WASHINGTON

APPROXIMATE BOUNDARIES

MANGANESE OCCURRENCES 2

(NUMBERS REFER TO TEXT)

SCALE

1½ 0 1 2 3 4 5 MILES