STATE OF WASHINGTON
Clarence D. Martin, Governor

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DEPARTMENT OF CONSERVATION AND DEVELOPMENT
J. B. Fink, Director

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# OLYMPIC PENINSULA MANGANESE

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Summary of Reports by Mineral Investigations Project, Work Projects Administration, sponsored by Department of Conservation and Development and Commissioner of Public Lands, with which is combined information obtained from other sources.

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by
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December, 1940

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## INTRODUCTION

For the purpose of obtaining more complete information on the occurrences of certain minerals, their extent and quality, especially strategic and critical minerals, the Department of Conservation and Development and the Department of Public Lands, sponsored a state-wide mineral investigations project, conducted by Work Projects Administration. A major undertaking under the project was investigation of manganese deposits on the Olympic Peninsula. It was the desire to determine, so far as it was possible to do so, the extent and quality of the ores in the manganese zone extending around the north, east, and south sides of the Olympic Mountains. While work conducted under the project, was, under the regulations, confined to public lands, it was recognized that the information thus obtained would be a very valuable addition to that already known or obtained from other sources. These investigations were begun in January, 1937, and were carried through to November, 1940. The work was concentrated in Grays Harbor County, south and east of Lake Quinault, and in Clallam County, mainly west of Lake Crescent.

The program of investigations was formulated and directed by the sponsors, through the Division of Mines and Mining. A state supervisor was employed, who had direct charge of all operations. Field supervisors were employed to have charge of the crews of WPA workers. A laboratory was maintained on the University campus through co-operation with the University of Washington, where all samples sent in from the field were analyzed.

During the operation of the project, until it expired in October, 1940, the state supervision was successively under the following geologists and engineers: Claude S. Fowler, Paul H. Knowles, and Edward J. Dailey. Amos Slater was the field supervisor in Grays Harbor County, and Stephen H. Green, and Pat Crane were field supervisors in Clallam County. Field camps were maintained on a co-operative basis. Field equipment was furnished by the sponsors and WPA. Substantial contributions in oil and gasoline for transportation, and in equipment, were made by the counties in which the work was being done.

Several agencies in the past have investigated certain of the manganese deposits. The published reports of the investigations were referred to frequently by the WPA mineral survey personnel in summarizing their work. A list of the references will be found at the end of this report.

The manganese deposits on the Olympic Peninsula have attracted much attention for many years. The predominant manganese ore consists mainly of the mineral bementite, a silicate of manganese with lesser amounts of manganese carbonate and manganese oxide. Sufficient manganese oxide occurred at the Crescent mine to be extracted and shipped in substantial amounts.

Heretofore the higher grades of domestic and foreign manganese have been available for ferroalloys. Domestic low-grade ores have not been exploited. The possibility of the supply of imported manganese being cut off and the dwindling of the amounts of high-grade domestic ore has stimulated various state and Federal and private agencies to advance processes to make possible the use of low-grade manganese silicate ore on the Olympic Peninsula for ferroalloys. The ore reserves are known to be large. Natural outcrops indicate hundreds of thousands of tons to be present. Trenching has exposed additional amounts. Diamond drilling by the United States Bureau of Mines and detailed surface examinations by the United States Geological Survey will no doubt disclose other manganese bodies.

## GEOGRAPHY

The Olympic Peninsula embraces the northwestern corner of the State of Washington. On the west, the peninsula is bounded 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 strip of lowlands drained by the Chehalis River and some of its tributaries.

The peninsula is bounded on three sides by tide water with numerous bays and inlets on the north and east sides. Ocean-borne commerce is available from Aberdeen and Hoquiam in the southwest part of the peninsula, to Port Angeles and Port Townsend on the north, and to Olympia in the southeast corner. Passenger and freight ferry service is available between the major cities on the mainland and the cities on the peninsula.

The southern part of the peninsula is serviced by two major railroads--the Northern Pacific which connects Olympia and Shelton with Hoquiam, Aberdeen, and Moclips; a branch of the Chicago, Milwaukee, St. Paul and Pacific Railroad connects Port Townsend with Port Angeles, and estends westerly as far as Joyce. At the town of Joyce, the Port Angeles and Western connects with the Chicago, Milwaukee, St. Paul and Pacific, and extends toward the west as far as Lake Tyee.

Several logging railroads are in operation on the peninsula. The Olympic highway entirely circles the mountains. Numerous side roads follow major drainage channels into the mountains for a few miles from the Olympia highway. These roads are rarely longer than twenty miles and the average length is probably much less.

Except along the margin of the Olympic Mountains the peninsula is one of relatively high relief. Beginning at sea level is a fringe of low land, hills, and ridges, some of which rise to an elevation of about 3,000 feet. The Olympic Mountains rise abruptly from this lower fringe and attain elevations up to and in excess of 7,000 feet. High, vertical cliffs, vertical-walled canyons, and serrated peaks are common. All the characteristics of a youthful stage of erosion are exemplified in the Olympic Mountains. U-shaped valleys, typical of glaciated areas, are in abundance. Valleys that do not show evidence of glaciation are an exception.

The Olympic Peninsula is one of comparatively mild climate.

Although the rainfall is excessive and considerable snow falls on the higher parts in winter, the range from minimum to maximum temperatures is not high. A few glaciers remain on the higher peaks throughout the year. Early morning fogs are common even in the middle of the summer season. Sea breezes bringing cool, fresh air from the ocean waters keep the midsummmer temperatures from becoming excessive.

A large number of rivers head in the Olympic Mountains. These rivers carry large volumes of water at times because the annual precipitation is heavy. Innumerable creeks and tributaries feed the major streams.

Dense forest covers most of the Olympic Mountains. Above the timber line on the higher mountains and peaks very little vegetation grows. Spruce, fir, hemlock, and cedar make up the major portion of the timber. Underbrush consists mainly of maple, willow, and alder.

## GEOLOGY

In general the geology of the Olympic Peninsula consists of a core of rocks of pre-Tertiary age almost entirely surrounded by a fringe of rocks of Tertiary and Quaternary age, composed of both marine sediments and volcanic rocks.

Mesozoic.--Inasmuch as the manganese ore bodies are found in rocks of Tertiary (Eocene) age, and examinations of these ore bodies are not dependent on a detailed knowledge of Mesozoic geology, only a very brief mention of the Mesozoic rocks will be made. These rocks are mainly graywackes and indurated sandy shales and sandstones.

Eocene--Metchosin Volcanics and Crescent Formation--The basement rocks of Eocene age on the Olympic Peninsula are the basaltic lavas, tuffs, agglomerates, and limestones called the Metchosin Volcanics. Except for the relatively thin beds of limestone, these rocks are composed entirely of volcanic materials. Clapp[1] has named and described these rocks where they occur on Vancouver Island.

Rocks of the Metchosin formation are found in many parts of western Washington and in northwestern Oregon.

Weaver[2] states that, "The lithologic description of the basaltic rocks of the Metchosin formation on Vancouver Island applies equally to the exposures of the same eruptive rocks around the margin of the Olympia Peninsula, in the Wildcat Hills of Kitsap County, the Black

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(1) Clapp, C. H., Geology of the Nanaimo map area: Canada Department of Mines, Geology Survey Memo 36, p 86.

(2) Weaver, Charles E., Tertiary Stratigraphy of Western Washington and Northwestern Oregon, University of Washington Publications in Geology Vol. 4, p 28 (1937).

Mountains of Thurston County, the hills between the Chehalis and Columbia Rivers and the low hills between Willapa and Grays Harbors."

Predominant among the volcanic rocks of the Metchosin formation are basaltic flow rocks. Considerable variation in color, texture, and mineral composition is seen between the various flows. These range from fine-grained to porphyritic and dense to vesicular. The porphyritic basalts contain scattered phenocrysts of plagioclase feldspar and augite. Some of the pores of the vesicular rock are filled with amygdules of calcite, quartz, epidote, and obicular jasper.

Pillow structure, in this case indicative of extrusion under water, is found in several of the flow members of the Metchosin volcanics. These pillows vary in diameter from a few inches to more than 2 feet. A finely crystalline material, white to pink to blue in color, that resembles aragonite, often surrounds and cements the pillows.

Fragmental type of volcanic rocks including tuffs and agglomerates are interstratified with the flow rocks. In amount these types are second in importance to the flow rocks. The tuffs and agglomerates range from fine-grained, banded rocks to agglomerates containing fragments of lava as large as 10 feet in thickness. Minor amounts of andesite flows and biabase dikes occur in the Metchosin formation.

The limestone is fine-grained, dense, and dark maroon to chocolate brown. It breaks with a splintery to conchoidal fracture and is quite friable. Large pieces, when broken into small fragments, show the typical color and texture all the way through. Usually the limestone is traversed by small veinlets of calcite.

On the Olympic Peninsula the Metchosin formation ranges in thickness between 2,000 and 3,500 feet. Weaver[3] states that the average thickness of the Metchosin formation on Vancouver Island approximates 3,000 feet. In the western part of the peninsula the formation is thickest, thinning considerably toward the east. Where exposed in the Newcastle Hills southeast of Seattle the formation probably is not over 1,000 feet thick.

Several colors are seen in different members of the Metchosin formation. The unaltered lavas are black and dark gray. Green is the prevailing color of the lavas that are completely altered to greenstone. In some places the altered lavas are red and brown, not unlike the color of the red limestone.

The rocks of the Metchosin formation have suffered differing amounts and kinds of alteration. As a result, the alteration products are different in different members.

Weaver[4] states that, "Perhaps 25 per cent of the lavas have suffered sufficient alteration to be classed as greenstones." In these greenstones,

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(3) Weaver, op. cit. p 28.
(4) Weaver, op. cit. p 28.

the minerals of the original lavas have been changed to epidote, chlorite, and serpentine in large part. Internally the rocks are slickensided due partly to swelling during alteration and partly to movement caused by deformational forces.

On external surfaces the rocks are brown, probably due to the production of limonite--the hydrous oxide of iron. Of considerable importance is a red phase of the greenstones produced either by weathering or the chemico-physical alteration of these rocks under somewhat unusual conditions. This red phase is found at or very near some of the manganese deposits; however, it is not always present. On the surface this rock is very similar in physical characteristics to the red limestone, but, the inner portions are found to be composed of altered greenstone. Undoubtedly the iron in the original minerals has been altered to hematite--the red, hydrous, iron oxide. The red color of this rock has led prospectors to assume that the rock is red limestone and that the ore is on the contact of the red limestone and the greenstones. This erroneous opinion has been responsible for the expenditure of much misdirected energy.

Pardee[5] in describing manganese deposits near Lake Crescent and Humptulips, presents a hypothesis on the origin of the ore that is based on replacement of the limestone by bementite. Manganese ore bodies would then only be found at those horizons where limestone had once existed.

Pardee further states that, "Under the hypothesis set forth above, prospecting for manganese ore should be guided by the geology. The red limestone-greenstone horizon should be located and searched for outcrops of manganese—bearing material."

It then becomes of importance to know the true nature of the red rock and to fully recognize what connection it may have with deposits of the manganese ore.

At least in the northern border of the Olympic Peninsula, the Metchosin volcanics lie unconformably on the arkosic sandstones of the pre-Tertiary Sol Duc formation. The contact between the Metchosin volcanics and the next younger formation appears to be conformable in some localities. Based on contact relations, type of rocks present, and character of the rocks, the Metchosin volcanics are thought to have been extruded and accumulated on a relatively smooth plain that had been slightly submerged below sea level. This plain, which possibly extended from Vancouver Island into California, may have been a coastal plain produced by the erosion of the tilted Mesozoic rocks.

In the northern border of the Olympic Peninsula the rocks of the Metchosin formation have a general strike of about N. 75°W. and dip between 45° and 70° toward the northeast; however, they are quite variable. Where the Metchosin volcanics outcrop in the eastern part of the peninsula, the strike of the lavas is about N. 40°E; the dip ranging around

(5) Pardee, U. S. G. S. Survey Bulletin No. 795 p 15 (1927).

$35^{\circ}$ to $45^{\circ}$ toward the southeast. In the vicinity south of Lake Quinault, the prevailing strike is nearly east-west and the dip probably not to exceed $10^{\circ}$ toward the southeast.

Weaver[6] describes the Crescent formation as containing the tuffaceous members at the top of the main volcanic sequence (the lower part of which is the Metchosin formation) as well as shales and sandstones which overlie the tuffaceous sediments. The Crescent formation is confined to the northern border of the peninsula. In thickness, it ranges between 600 and 5,600 feet.

Lithologically, the Crescent formation consists of a basal series of black shales underlying thinly bedded tuffaceous shales containing some flows of vesicular and agglomeratic basalt and thin lenses of tuff. The upper half of the Crescent formation, consisting of shales and layers of sandstone, becomes progressively more sandy toward the top.

Oligocene.--The Oligocene is represented on the peninsula by a maximum thickness of about 20,000 feet of sandstones, sandy shales, shales, and conglomerates. Three formations make up the rocks of Oligocene age. In the Lyre area, basal rocks of the Oligocene consist of 750 feet of sandstone and conglomerate lying upon rocks of the Crescent formation. Approximately 4,150 feet of alternating layers of shaly sandstone, sandstone, and sandy shale lie conformably on the conglomerate. These rocks constitute a lithologic unit called the Lyre formation.

Stratigraphically above, are the sandy, clay-shales of the Lincoln formation which rest upon the rocks of the Lyre formation in apparent conformity. Weaver[7] measured a thickness of 6,000 feet of rocks of the Lincoln formation between Whiskey Creek and a point on the coast five miles west of Gettysberg.

Conformably overlying the Lincoln formation are the shaly sandstones with interstratified layers of shale and sandstones of the Blakely formation. These rocks are exposed in the sea cliffs between the mouth of Sekiu River and the north shore of Cape Flattery. At the latter locality, the Blakely formation varies in thickness between 3,000 and 4,000 feet.

Miocene.--In the northern part of the peninsula, rocks of the Clallam formation are exposed. These rocks consist of massive sandstones, conglomerates, shaly and pebbly sandstones, and clay-shales. Good exposures exist in the area along the coast between the mouth of Clallam River and Pysht. Basal rocks of the Clallam formation appear to rest unconformably upon the Oligocene rocks.

Between the southern flank of the Olympic Mountains and the Columbia River, exposures of the Astoria formation occur. These exposures can be seen along tributaries of the Satsop, Wynoochee and Wishkah Rivers in Ranges 5 to 9 W., T. 19 N., and in the valleys of the Wishkah,

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(6) Weaver, op. cit. p. 29.
(7) Weaver, op. cit. p. 121.

Wynoochee and Hoquiam Rivers in Ranges 8 and 9 W., T. 18 N. The rocks are mainly brownish-gray sandstone with intercalations of tuffaceous shale. All of these become finer grained toward the west. A thickness of 2,500 feet was measured by Weaver[8]. These strata rest unconformably on the sandy shales of Oligocene age in the Wishkah syncline.

Pliocene.--Rocks of Pliocene age on the Olympic Peninsula consist of sandstones, shaly sandstones, and conglomerates of the Montesano, Quinault, and Quillayute formations, all of which are of limited extent. The Montesano formation, composed mainly of sandstones and conglomerates, is about 2,000 feet in thickness. The Quinault formation probably is not much in excess of 1,500 feet in thickness. Similar to the Quinault formation is the Quillayute formation with a maximum thickness of 1,000 feet or under.

## MINERALOGY

The principal manganese mineral is bementite a silicate of manganese. It is waxy brown to blood red in color and ranges from opaque to translucent. The deeper red varieties are more translucent. Other manganese minerals identified in the ore bodies are neotorite, rhodonite, rhodochrosite, and the manganese oxides, hausmannite and pyrolusite.

Normally bright red jasper composed of quartz and red iron oxide accompanies the manganese minerals. Some of the siliceous material resembles the jasper even to fine-banded structure, yet alters to black manganese oxides.

Native copper occurs in several of the manganese deposits. The Tubal Cain mine was originally opened as a copper mine on a manganese deposit in which native copper occurs. In the Black and White mine native copper occurs in specks and flakes disseminated through the bementite rock. Traces of gold have been found by assay in some samples of the manganese ore.

A small vein of cinnabar about one-half inch in thickness occurs in the ore body exposed on the north bank of a tributary of Beaver Creek. This deposit is located in the SE¼ SE¼ Sec. 16, T. 30 N., R. 12 W. Cinnabar was found in one sample of ore from an exposure located in the NW¼ Sec. 25, T. 30 N., R. 11 W. This ore occurrence is on the east bank of a small stream which flows nearly to the Olympic highway very near the line between Sections 25 and 26. Similar occurrences are known in the manganese deposits of the Sol Duc Burn area.

The following descriptions are of some of the principal manganese minerals found on the peninsula:

### Bementite

Composition: $8MnO.\ 7SiO_2.\ 5H_2O$.

(8) Weaver, op. cit. p 121

Structure: Usually finely crystalline. Where coarsely crystalline, it tends to be spherulitic.

Physical Properties: Hardness = 6. Tough, and breaks with splintery fracture. Fresh bementite varies from light gray to grayish brown in color. Vitreous luster. Transparent in splinters. Splinters soon become dull and opaque. Fresh samples of the bementite become dull after being exposed to the air for two or three weeks. Specific gravity = 3.106.

Occurrence: Except for the occurrences on the Olympic Peninsula, where bementite makes up a considerable proportion of the rock, it is a rare mineral of little value.

## Neotocite

Composition: $MnO \cdot SiO_2 . nH_2O$. Composition variable.

Structure: Amorphous.

Physical Properties: Hardness = about 4. Brittle. Breaks with conchoidal fracture. Color varies from reddish-brown to jet black. Resinous luster. Specific gravity = 2.6.

Occurrence: In the Olympic Peninsula ores, neotocite occurs in small veinlets cutting the bementite.

## Rhodonite

Composition: $MnSiO_3$. Iron, calcium, and sometimes zinc replace a part of the manganese.

Structure: Cleavable to compact, granular, massive, and as embedded, dissemenated grains. Often as crystals which are rough with rounded edges.

Physical Properties: Hardness = 5.5-6.5. Brittle. Vitreous to dull luster. Rose-red, pink, to brown in color. Often coated with black manganese oxide after exposure to air. White streak. Transparent to opaque. Specific gravity = 3.4-3.68.

Occurrence: Occurs with iron ore in Sweden and in large masses in the Ural Mountains. Associated with zinc at Franklin Furnace, New Jersey. In the Olympic Peninsula manganese deposits, rhodonite occurs as veinlets cutting the bementite and as crystals embedded in the bementite.

## Rhodochrosite

Composition: $MnCO_3$. Iron usually present, replacing part of the manganese. Sometimes calcium, magnesium, zinc, etc. replace part of the manganese.

Structure: Occurs as crystals in radiating masses, massive and granular masses. Rarely compact, botryoidal, and incrusting.

Physical Properties: Hardness = 3.5-4.5. Vitreous to pearly luster. Dark red or rose-red when transparent, light pink to brownish-red when translucent or opaque. Exposed surfaces become dull to black-sub-metallic due to formation of manganese oxides. White streak. Specific gravity = 3.45-3.6.

Occurrence: Usually associated, as veins, with other manganese minerals and ores of silver, lead, copper. In the Olympic Peninsula ores, rhodochrosite occurs as veins and veinlets cutting the other manganese minerals. A minor ore of manganese except in the Montana manganese deposits.

Hausmannite

Composition: $Mn_3O_4$. An important constituent of the high-grade ore shipped from the Crescent mine, that probably accounted for the high manganese content of the ore.

Structure: Finely crystalline, dense, massive, to aggregates of fine black grains where it occurs at the Crescent mine.

Physical Properties: Hardness 5-6. Brittle. Varies from darker shades of brown to dense, blue-black in color. Has dark to chestnut brown streak. Specific gravity = 4.72-4.86.

Occurrence: Associated with manganese silicates in some primary deposits. Generally occurs with braunite in secondary concentrations. In the Crescent mine, hausmannite occurs in masses and also in veinlets cutting other masses of hausmannite.

Pyrolusite

Composition: $MnO_2$. Commonly contains a little water.

Structure: Crystals radiating columnar to fibrous, also granular massive. Often occurs in reniform coats. Crystals probably always pseudomorphous after manganite.

Physical Properties: Hardness = 2-2.5. Usually soils the fingers. Metallic to dull earthy luster. Iron black color and streak. Splintery fracture. Specific gravity = 4.75.

Occurrence: A secondary mineral, usually. Occurs as a primary constituent in sedimentary deposits. Nodular deposits of pyrolusite are found on the sea bottom. Replaces such minerals as rhodochrosite, rhodonite, braunite, hausmannite, psilomelane, manganite, and manganosite. Probably occurs as a secondary mineral in the Olympic Peninsula ores.

## ORE DEPOSITS

General.--Deposits of manganese ore on the Olympic Peninsula are found in the Metchosin volcanics. Very likely, the deposits are confined to certain specific members of this series of rocks although such has not been demonstrated as yet. At least the ore is associated with the altered, basic flow rocks, and is sometimes found to occur between these rocks and the red limestone. Some of the ore occurrences are in the altered pillow lavas and some are in the greenstone that do not show the pillow structure.

The known manganese deposits occur in a horse shoe-shaped belt approximately one hundred ten miles in length. One end of the belt is in T. 32 N., R. 15 W. (Clallam County on the Pacific Ocean) on the north; the other end is in T. 23 N., R. 12 W. (Grays Harbor County) on the south. The toe or east end of the belt is found in the eastern part of Jefferson County.

Size of Outcrops.--Outcrops of the manganese ore vary considerably in size. A few natural outcrops of ore 300 feet long, 85 feet wide, and standing in bold cliffs 200 feet above the surrounding rocks have been observed. However, most of the outcrops are very small; many are only a few feet long and 2 or 3 feet wide. Except for the relatively few places where the ore stands out in bold cliffs, the manganese ore has been eroded equally with the enclosing rocks so that the outcrops of ore assume no topographic prominence.

Many of the ore deposits are covered with overburden of soil and debris. Some of the deposits have been capped and covered by flows of basalt younger in age than the enclosing Metchosin rocks. Some of these flows belong in the Metchosin formation and some are unquestionably younger than the last flows of this formation.

Shape of Ore Bodies.--In shape, the ore deposits are variable. Probably lenses and lenticularly shaped bodies (that usually are thicker in the center and thin out on the edges) are most numerous. It has been found by mining experience that lens-shaped ore bodies are usually about as wide as they are long. In view of this, the lenses of manganese ore on the Olympic Peninsula cannot be expected to be much wider (down the dip) than they are long (along the strike). In the past many tunnels have been driven in the hope of finding the ore from 2 to several hundred feet below the outcrop. Almost without exception these tunnels have failed to reach the ore. Before development of the ore bodies is undertaken some diamond-drill tests should be made to determine the actual confines of the ore. If other development means are employed, until the boundaries of the ore bodies are known, such development should be confined to the ore body.

Tabular-shaped ore bodies are found which might be almost any width as compared to the length. The occurrence on the Lucky Creek group is a good example of a tabular-shaped ore body.

Physical Character of Ore.--In general, the ore is dense and massive with a vitreous to dull metallic luster. Fresh surfaces of the ore not uncommonly exhibit bright metallic luster which dulls on exposure for a short period of time. Weathered surfaces are both metallic and earthy in appearance.

Wide variation in color is experienced between ores from different deposits and between different samples of ore from the same body. Weathered surfaces exhibit tan, reddish-brown, brown and black colors. Freshly broken faces show numerous shades of red, brown and black.

Depending upon the minerals present, the fracture of the ore is variable. In the main, the fracture is irregular but occasionally is flatly conchoidal. Most of the ore bodies show very irregular jointing. Talus, found at the foot of the more prominent outcrops, consists of ore ranging from small fragments to blocks up to three feet in diameter. Except for weathered portions, the ore is relatively hard.

Weathering of Ore.--Weathering of the ore has not progressed to any great extent or depth. Outcrops that have been exposed probably for centuries show surprisingly fresh faces. Obviously, spalling is keeping apace with if not in advance of oxidizing in these places. In the less prominent exposures where spalling is reduced to a minimum, only a thin layer of oxidized ore is found which rarely exceeds a few inches in depth. It is reasonable to expect that persistent fractures in the ore bodies will be found and weathered products may exist to depths of 20 ór more feet from the land surface.

Attitude of Ore Bodies.--At places where the walls of the ore bodies are well defined and where the deposits are in contact with limestone the attitude of the ore bodies can be measured quite accurately. Much greater difficulty is experienced in determining the attitude where the ore bodies are enclosed in greenstone. In general, it may be said that the ore bodies conform in dip and strike to the dip and strike of the enclosing rocks.

Contact Relations.--Usually the contact of manganese ore with red limestone is fairly sharp. Quite different are the contacts of the ore bodies with greenstone. In most cases where the ore is in contact with greenstone, the contacts are indiscernable because the ore grades outward into rock that is only stained with manganese materials.

Some of the manganese deposits are enclosed in lava rock that is only slightly altered. While the contacts of these ore bodies are not knife-edges, they can be defined within limits of a few inches with reasonable accuracy.

Quality.--Original minerals make up the major portion of the manganese deposits; minerals produced by weathering are in such minority as to be practically negligible.

The primary minerals (those composing the unweathered ore) are a complex combination of manganese silicates and oxides, quartz, and iron oxide. Silicate minerals are present in all the deposits so far discovered. Likewise, oxides are ever present. Some investigators are of the opinion that oxides should predominate at depth, but the field evidence appears to contradict this statement. In view of the fact that, on the average, the deposits are of limited depth, it seems unreasonable that conditions of deposition would have changed very much for any one deposit.

## COMPOSITION

The manganese content is extremely variable. Analyses show that the manganese content is as high as 50 to 60 per cent and as low as 10 per cent and under. However, an average of forty-two analyses showed 33.67 per cent manganese. These analyses were of samples collected from twenty-two different deposits mainly in the northern part of the peninsula. It will be found that some variation in manganese content will be found in different parts of the deposit but this variation should not be great.

Variations in iron content are to be expected. The same forty-two analyses showed an average iron content of 12.12 per cent with a high of 27.08 per cent and a low of 1.30 per cent. Some deposits on Aurora Ridge, which are exceptional in iron content, contain a high of 44.28 per cent of iron, 30.22 per cent manganese, and under 15.00 per cent of silica.

Silica, a chemically combined constituent of the ores, also varies in amount. An average of the forty-two analyses showed 15.26 per cent silica, with a high of 34.20 per cent and a low of 8.00 per cent.

Phosphorus ranged between .025 and .049 per cent in eight of the forty-two analyses mentioned above. The phosphorus content as shown in these eight analyses averaged .032 per cent. Sulphur in seven analyses of the forty-two, showed a trace in five samples and none in the other two.

Many more analyses beyond the above forty-two mentioned were made, but their averages do not materially change the above figures. They merely show in the assay tables the records of specific deposits.

## DISTRIBUTION OF OCCURRENCES

For the purpose of description, the manganese occurrences are arbitrarily divided into the following areas: West of Lake Crescent, Aurora Ridge, Storm King, Little River, Iron Mountain, Dosewallips River, North Fork Skokomish River, Steel Creek and Quinault areas.

West of Lake Crescent Area

In this area the manganese deposits occur on the south slope of a long, serrated ridge which extends from Pyramid Mountain, past Mount Muller to Snider Peak. Exposures of ore are found in the broad valleys of Bear and Beaver Creeks at the western terminus of this ridge. Still farther west, occasional occurrences are reported between the valley of Beaver Creek and a point on the coast northwest of Ozette Lake. In many respects the deposits in this area are sufficiently similar that a detailed description of one deposit would be representative of the district. The deposits in this area are divided into five localities, namely: Lake Crescent, Sol Duc Burn, Bear Creek, Beaver Creek, and Sekiu River.

Westward from Lake Crescent, the Olympic highway closely parallels the south slope of the ridge to its end. Most of this distance (about twenty-three miles) the highway is not more than one-half mile from the base of the ridge.

The deposits located in the vicinity of the west end of Lake Crescent can be reached by a county road which extends from Fairholme (on the west end of the lake) to Ovington, a distance of three miles. A private road about one fourth of a mile in length connects the Crescent mine with the Olympic highway one and two-tenths miles west of Fairholme.

On the Sol Duc Burn, the deposits are accessible from the Olympic highway. Several tributary forest roads connect many of the deposits with the highway.

The Bear Creek deposit can be reached from the Olympic highway by travelling the Rainy Creek road a distance of two miles. From the Olympic highway at Sappho, the Beaver Creek deposit is reached by travelling the Clallam Bay road northward for one mile to the junction of the Rainy Creek road. This road is traveled in a northeasterly direction for a distance of three miles. From this point on the road, a trail, three eighths of a mile long, is followed in a westerly direction to the deposits.

From the Pyramid Mountain to west of the Crescent mine, the main line of the Port Angeles and Western Railway follows the base of the ridge. Approximately one-half mile west of the Crescent mine, the railroad turns southwesterly to the south side of the Sol Duc Valley. Following the south side of the valley, the railroad parallels the highway at a distance of approximately one-half mile to and beyond the town of Sappho.

In addition to the specifically located deposits, it is now definitely known that the manganese-bearing formation extends to the Pacific Ocean. Considerable manganese float has been found on the westward-flowing tributaries of the Soess River in the southern Neah Bay area.

<u>Lake Crescent Locality-Crescent Mine</u>.--The Crescent mine is near the line between Sections 23 and 24, T. 30 N., R. 10 W., about one and

one-fourth miles west of Fairholme. In September, 1923, the ore body was discovered at an elevation of about 1,800 feet on the south slope of Mount Muller Ridge. About the middle of 1924, Jamison and Peacock, of Duluth, Minnesota, began producing ore which was shipped via the Panama Canal to Philadelphia. Mineral Resources of the United States, published by the United States Bureau of Mines reports the following production for the Crescent mine: 1924 - 5,000 tons; 1925 - 8,113 tons; 1926 - 3,162 tons.

The ore body was tabular in shape, 180 feet long, 120 feet wide, and from 6 to 14 feet thick. Manganese content was high, ranging between 50.92 per cent and 54.33 per cent. Silica averaged between 7.78 per cent to 8.93 per cent. Very little iron was contained in the ore and ranged from 0.74 per cent to 1.13 per cent. Phosphorus pentoxide averaged 0.054 per cent. It can be seen that the ore was high grade, having a high content of manganese and a low content of undesirable materials. This is probably due to the fact that the ore was chiefly hausmannite with minor amounts of bementite and manganese carbonate.

About one-fourth mile northeast of the portal of the long tunnel at the Crescent mine, on the Peggy claim, an outcrop of ore about four feet thick occurs in Sec. 24, T. 30 N., R. 10 W. The ore in this outcrop has a massive appearance and may be the exposure of a substantial lens. A diamond-drill hole cut this ore body at a depth of 135 feet below the surface. It is reported that the ore body could be tapped from some of the underground workings of the Crescent mine. Analyses made in 1934 show the ore to be of considerably higher grade than the average for this area.

Eastward from the Peggy claims are several outcrops near the common corner of Sec. 19, T. 30 N., R. 9 W. and Sec. 24, T. 30 N., R. 10 W. and Sec. 25, T. 30 N., R. 10 W. and Sec. 30, T. 30 N., R. 9 W. The outcrops occur at an elevation of 2,100 feet. Exposures show the ore body to average between 4 and 6 feet in thickness. The exposures extend over a lateral distance of 300 feet. It has not been demonstrated that the exposures are on the same ore body, however.

Two other outcrops occur 100 feet up the hill from the county road to Ovington. The discovery post is 67 feet east and 7 feet north of the SW corner of Lot 4, Sec. 30, T. 30 N., R. 9 W. The ore body is from 4 to 6 feet in thickness.

<u>Sol Duc Burn Locality</u>.--On the Sol Duc Burn, which is on the south slope of the ridge between Mt. Muller and Snider Peak and the north wall of the Sol Duc Valley, are between twenty-five and thirty known exposures of manganese ore.

Up to the present time it has been found that the most exposures occur in a belt between 1,500 and 2,500 feet in elevation. However, this must not be taken to mean that no outcrops will be found outside of this belt. One outcrop has been found one-half mile east of Kloshe Nanich Lookout at an elevation of about 2,300 feet, that from present appearances, may prove to be of considerable importance. Investigations to date lead to the conclusion that the larger ore bodies are confined to certain members of the Metchosin formation which crop out of the hillside in the above horizon in this area. In the majority of the larger exposures in the area the ore has a massive appearance.

Progressing toward the west from the Lake Crescent locality, the first showings encountered are found in Sec. 23, T. 30 N., R. 10 W., in the NW$\frac{1}{4}$ of the NW$\frac{1}{4}$, at an elevation of 2,340 feet. An outcrop approximately 24 feet in length by an average width of 6 feet and a depth of 12 feet was stripped. The ore outcrops at the foot of a high cliff and is enclosed in greenstone. Red limestone is in evidence approximately 75 feet south of the exposure. The ore is very massive in appearance and gives evidence of being the top of a sizeable lens.

Continuing westward, the next occurrence opened is near the center of the north half of Sec. 21, T. 30 N., R. 10 W. Here three trenches have been dug. The first one (Trench No. 3) at an elevation of 1,905 feet, exposed an outcrop 30 feet 4 inches in length by an average width of 6 feet. Four hundred and seventy-six feet northwest of Trench No. 3 Trench No. 1 was opened exposing an outcrop approximately 23 feet long with an average width of over 6 feet and a depth of 14 feet. Trench No. 2 failed to reach ore in place, only float was encountered.

Twenty-six hundred and forty feet west of the above locality another outcrop was opened by two trenches at an elevation of 1,875 feet. One of these exposed an ore body 22 feet in length by an average of 12 feet in width and the other 10 feet in length by 6 feet in width. The ore consists of bementite containing in places small amounts of cinnabar.

Along Littleton Creek in Sec. 20, T. 30 N., R. 10 W., there are two exposures of manganese. One outcrop, about 14 feet long and 10 feet high, occurs about 100 feet east of the stream at about the 1,400 foot elevation. Analyses of samples show that the ore is of higher grade than the average in this area. Approximately 300 feet higher in elevation and on the west bank another lens is exposed and is about 9 feet long by 5 feet high.

Two separate exposures have been found recently which indicate the possibility of being fairly large lenses of good ore. One lens occurs at the 1,400 foot elevation about 500 feet west of Littleton Creek. Approximately 700 feet west of this occurrence the other lens is exposed in the west bank of a small canyon. The outcrop is about 10 feet long and 6 feet high.

June Group.--Locally called the June Group, in the SE quarter of the SW quarter of Sec. 19, T. 30 N., R. 10 W., an outcrop occurs. This showing is the lowest of any deposit found to date, on the Sol Duc Burn, being at an elevation of 1,265 feet. It has been opened by a small shaft 16 feet deep by 13 feet by 9 feet in section. Trenching on both sides of the shaft has been done to show the extent of the outcrop.

The deposit lies between unaltered basalt on the south and red limestone on the north. The basalt next to the ore is the vesicular type with calcite forming stringers and filling the vesicules, but away from the ore grades into the more massive, aphanatic, and heavily stained type. The ore is in place on both sides of the shaft and continues to the floor of the same where it is still in evidence.

The lens stands vertical with a strike of S 76° E. Subsequent mineralization is indicated by small veinlets of cinnabar cutting the ore.

Ed B. Group.--The exposures in parts of Sec. 19, T. 30, R. 10W, Sec. 24, T. 30, R. 11 W. are locally known as the Ed. B. Group. In the SW quarter of Sec. 19, T. 30 N., R. 10 W., an outcrop has been uncovered by stripping, showing a total length of slightly over 260 feet and an average width of over 25 feet. About 100 feet to the east another large open pit exposes ore for 64 feet in length and 35 feet in width. It is possible this is one lens, instead of two, but the 100 feet between them is covered by heavy overburden. The strike follows the general trend of all the ore bodies in this locality. The elevation at the east end is 1,765 feet and rises to 1,825 feet at the west end.

In the SE quarter of Sec. 24, T. 30., R. 11 W., manganese ore is uncovered. This occurs at an elevation of 1,545 feet on the east side of Eureka Creek. The stripping and trenching has disclosed a body of ore with a length of 125 feet and a width of 82 feet. Pits at the face, to a depth of 10 feet, expose the ore. It is the largest body so far discovered on the Burn and undoubtedly will produce a considerable tonnage. The exposure lies between greenstone and red limestone. One distinctive feature of this occurrence is that the red limestone accompanying it grades into limonite, with small patches of hematite.

In the SW ¼ of the NE ¼ of Sec. 24, T. 30 N., R. 11 W., ore is exposed by three trenches at an elevation of 2,192 feet. This is locally known as the Sunrise claim. Trench No. 1 shows ore 50 feet 6 inches in length by an average width of 4 feet. Trench No. 2 shows a length of 26 feet and an average width of 3 feet. Trench No. 3 is 21 feet in length with an average width of approximately 4 feet. While Trenches Nos. 2 and 3 have not been joined, it appears likely that it is a continuous body in which case it would have an overall length of approximately 100 feet. The ore is enclosed between greenstone and red limestone. It stands vertical and strikes N 75° W.

Continuing westward the next occurrence was found at a distance of approximately 700 feet at an elevation of 2,135 feet. A trench at this point exposes an outcrop 82 feet in length by an average width of 24 feet six inches. About 75 feet below the trench a tunnel has been driven into the greenstone for 45 feet. No ore shows in the tunnel but in the face of a short cross-cut to the right manganese was cut. This exposure is on the east wall of a wide canyon; directly across the canyon on its west wall is an outcrop of the red limestone.

Six hundred feet westerly in the N½ of the SW¼ of Sec. 24, T. 30,

R. 11 W., at an elevation of 2,260 feet two trenches have exposed ore. In Trench No. 1 the outcrop is 54 feet in length with an average width of 19 feet. The ore is particularly massive and it is believed is the top of a large lens. Trench No. 2 exposes a length 34 feet with an average width of over 8 feet. There is a distance of about 100 feet between these trenches. This ore is entirely surrounded by red limestone. Seventy-five feet west of Trench No. 2 there is an outcrop of basalt.

In the SE¼ of Sec. 23, T. 30 N., R. 11 W., at an elevation of 1,735 feet and about 1,200 feet west of the above exposures another outcrop has been uncovered. The trench shows an ore body 32 feet in length and 8 feet in width. The ore at this locality is enclosed in greenstone.

Twenty-seven hundred feet farther west and about 350 feet west of the Kloshe Nanich Pack Trail at an elevation of 2,320 feet a greenstone outcrop on the east wall of the canyon was examined. Two lenses of ore were uncovered in the center of this outcrop. Trench No. 1 shows 20 feet of ore averaging 5 feet in width. Trench No. 2 exposes a lens of manganese 16 feet in length and 5 feet in width.

Examinations in Sec. 22, T. 30 N., R. 11 W. have not revealed any ore bodies. The terrain in this section is extremely rugged, and prospecting is difficult.

In the SE ¼ of Sec. 21, T. 30 N., R. 11 W., at an elevation of 1,845 feet a trench uncovered an outcrop 25 feet in length by 12 feet in width. This ore is enclosed in altered vesicular basalt. Fifteen hundred feet west three more trenches expose the following occurrences: In Trench No. 1 at an elevation of 1,675 feet the outcrop is 54 feet in length with an average width of 10 feet. In Trench No. 2., elevation 1,615 feet, the outcrop is 20 feet long and 4 feet wide. In Trench No. 3, elevation 1,745 feet, there is an outcrop 26 feet in length with an average width of 5 feet. All of these outcrops lie between greenstone and limestone. The ore is massive in appearance. In uncovering the ore in Trench No. 2 a pocket of approximately two pounds of cinnabar was encountered lying between the manganese and enclosing limestone wall rock.

Bear Creek Locality.--The Victor Lode or Bear Creek exposure is in the NW quarter of the SW quarter of Section 24, T. 30 N., R. 12 W. It is reached via the Rainy Creek road thence by approsimately 1,600 feet of trail adjacent to Bear Creek. The lens lies between two flows of basaltic breccia. No.limestone is in evidence, but a large body of red limestone is in place about 300 feet west of and above the ore body.

The outcrop was less than a foot in width but widened to over 6 feet when exposed at a depth of several feet. However, within a short distance it again diminished to a width of only one foot. It is possible, that if this lead were followed still farther, another and larger body would be opened up. The contact between the ore and the breccia is very irregular.

The ore is largely bementite with some neotocite and has the appearance of being high in silica. Some of the bementite is dark red and some is the glassy, translucent variety, which occurs in masses two or three inches in diameter, interspersed through the ore. The ore shows little evidence of oxidation, possibly because it is tightly enclosed in basalt, and thus being less susceptible to weathering agencies.

On the ridge extending from Bear Creek to Beaver Creek prospecting disclosed several outcrops of very massive ore. From the ore examined it is believed it is possibly of somewhat higher grade than the average. Trenching has not been completed in this area.

Beaver Creek Locality--(State Lease Group)--The Beaver Creek exposure known as the State Lease Group, is near the center of the NW ¼ of the SE¼ of Sec. 16, T. 30 N., R. 12 W. about two miles NE of Sappho. It is situated in a small canyon, a tributary to Beaver Creek. The ore crops out at the foot of a slide on the east side of the creek.

This deposit has been opened up by trenching and sluicing and by a tunnel 70 feet in length which cuts the ore about 10 feet below the bottom of the trench. As exposed at present, the lens is shown to be a continuous body of 34 feet long 15 feet wide and slightly over eight feet thick. Wall rocks are red limestone with some concentrations of iron oxide. A thick basalt flow overlies the limestone, while the underlying rock in the creek and in the opposite bank is sandy shale.

The ore is largely hausmannite with smaller amounts of bementite and neotocite. This deposit is of somewhat higher grade than the average, owing, to the predominance of hausmannite. It is also noticeably more massive than the average ore of this area.

Sekiu River Locality.--In the SE quarter of Sec. 27, T. 32 N., R. 14 W., an exposure has been found approximately ten miles west of the Hoko River bridge. The manganese appears to be of excellent grade. Cinnabar has been noted several times and free quick-silver present occasionally. To date no work has been done. The outcrop is 22 feet long and 7 feet wide.

The proximity of this deposit (only one mile) to the main line of the Bloedell-Donovan Logging R.R. and with an abandoned spur within 500 feet of the deposit, together with the high quality of the ore makes this deposit of particular interest.

An occurrence of ore is reliably reported in the SE¼ Sec. 27, T. 32 N., R. 14 W., which is west of the Hoko River. The deposit is on a tributary of the South Fork of the Sekiu River, and reached by trail a distance of five or six miles from the Clallam Bay-Ozette Lake road.

## Aurora Ridge Area

Aurora Ridge trends northwest-southeast between Aurora Peak and Lizard Head Peak, south of the eastern end of Lake Crescent. It rises from the lake level to elevations of more than 5,000 feet.

Three manganese exposures lying on the north slope of Aurora Ridge at approximately the 5,200 foot level are known. The deposits lie in the headwaters of the third tributary on the south side of Barnes Creek, in what probably would be Sec. 7, T. 29 N., R. 8 W. if the area were surveyed. A trail branching from the Olympic highway about one mile east of Lapoel leads directly to Aurora Peak and thence follows the crest of Aurora Ridge. The distance, by trail, is approximately eight miles to the deposits. An easier route, although four or five miles longer, is over a trail which branches from the Sol Duc Hot Springs road about four miles from its junction with the Olympic highway.

Manganese Deposits.--One outcrop is exposed on the face of a bluff several hundred feet high. On the top of the bluff the ore is exposed for a length of 125 feet. The ore body is about 50 feet in thickness. The ore on the face of the cliff cannot be reached, but is exposed for an estimated vertical distance of 175 feet.

Toward the east is another body of ore enclosed in red limestone. Very little is known about the extent of this body. About one and one-half miles east, on the crest of the ridge, is a deposit about fifteen feet in thickness; the length has not yet been determined.

### Storm King Area

Deposits of manganese are located on the north slope of Baldy Ridge which connects the peaks of Mount Baldy and Storm King mountain. The outcrops are due south of the center of Lake Sutherland in what would be Sec. 29, T. 30 N., R. 8 W., if the area were surveyed. These outcrops occur at an average elevation of 3,400 feet.

From the site of the old Erickson logging operations at the east of Lake Sutherland, the mountain side must be traversed in a direction slightly west of south. For a distance of three and one-half miles from the Olympic highway at Lake Sutherland to the outcrops, the rise in elevation is about 2,800 feet.

Manganese Deposits.--Outcrops of ore or rocks are scarce, as the slope is heavily timbered and covered with overburden of glacial debris and top soil. The outcrops are situated in a basin at the mouth of a glaciated U-shaped valley. Over the basin floor are strewn innumerable pieces of manganese float. These fragments of float range in size from a few inches to 2 or 3 feet in diameter.

An open cut exposed an ore body 6 feet in thickness and 7 feet in depth. However, the floor of the open cut is still in ore. In this cut the ore body appears to widen toward the face. Analyses of the ore made in 1934 showed the ore to be of about average grade.

### Little River Area

In the valley of Little River are eight known exposures of manganese ore. These deposits are within ten miles air line south and a little west of Port Angeles. With the exception of the Skookum and the deposits on the south side of Mt. Angeles (Third Peak) the deposits are situated in the walls of the cirque in which Little River heads. Elevations range between 3,200 and 5,200 feet.

Either of two routes can be followed to reach these deposits. One is a road to the summit of Hurricane Ridge, which forms the south and west walls of the cirque, via Elwha Ranger Station and the Hurricane Hill Lookout road. At the eleven-mile post (from Elwha Ranger Station) on the Hurricane Hill road, a trail turns eastward down the hill to Whistler Flats on Little River.

The other route is over the Black Diamond road to Coleman's ranch, a distance of five miles. From here, a good forest trail, suitable for pack animals, follows the Little River to its source beyond Whistler Flats. The deposits are accessible from this trail which is about seven miles in length. Recently a good grade has been surveyed and located with a view of tapping the ore deposits in this area.

Manganese Deposits.--Two exposures, known locally as the Skookum, occur at an elevation of 3,900 and about 4,500 feet in what probably would be Sec. 12, T. 29 N., R. 7 W., if the area were surveyed. These deposits are on a ridge trending northward from Unicorn Peak. At the 3,900 foot elevation, one outcrop has been extended along the strike for 200 feet by four open cuts. At the higher elevation, the outcrops have not been extended, but this appears to be an entirely separate ore body differing in attitude from the lower body. The ore is exposed for a vertical distance of 20 feet and is 25 feet in thickness.

Southwest of Whistler Flats, on a spur connecting Unicorn Peak and Hurricane Ridge, manganese ore outcrops in bold cliffs. These exposures are in what would be Sec. 24, T. 29 N., R. 7 W., had the area been surveyed. As exposed in the cliffs, there are several different ore bodies. These deposits stand vertical and range in height from 120 to 300 feet. The ore varies in width from 2 to 5 feet. With the exception of places where the ore bodies are masked by narrow patches of talus or younger basalt, the ore is exposed for a lateral distance in excess of one-fourth mile.

For a distance of two miles along the crest of the ridge extending westerly from Hurricane Hill Lookout, several small natural outcrops of ore occur.

South of Whistler Flats, on a ridge locally known as Hutton Ridge, are several bold outcrops of manganese ore. About one mile south of the cabin on Whistler Flats, the first known deposit is exposed between elevations of 4,020 feet and 4,200 feet. This deposit has been opened by open cuts exposing the ore over a lateral distance of 259 feet. An open cut on the other side of the ridge at an elevation of 4,190 feet exposes an outcrop of ore which may be an extension of the same ore body although it is covered for the 380 feet separating the two open cuts. In width, the ore body ranges from 6 to 43 feet, averaging about

20 feet where exposed.

About half a mile south is a ridge on the crest of which ore is exposed intermittently for a distance of about three quarters of a mile. The western portion of this ridge stands up in cliffs from 20 to 50 feet in height. In many places, these cliffs are composed almost entirely of ore. On the western end of the ridge, the exposures are more than 500 feet lower in elevation. Massive outcrops of the ore range in width from 20 to 125 feet, in length from 50 to 200 feet and in height from 20 to 50 feet.

On the south side of the Third Peak of Mt. Angeles, are some exposures which are reported to be of substantial size.

### Iron Mountain Area

Iron Mountain is at the headwaters of the Big Quilcene River and Copper Creek which is a tributary of the Dungeness River, in Jefferson County. The Tubal Cain mine is on the northwest side of Iron Mountain in Sec. 7, T. 27 N., R. 3 W.

The area can be reached by either of two routes. One route is by the Louella Guard Station road which branches from the Olympic highway about two miles west of Blyn. Eight miles from the highway at the Camp Colonel shelter, a trail follows the east side of Dungeness River to Copper Creek, thence up Copper Creek to the mine—for a total distance of about nine miles.

The other route is by road along the Big Quilcene River for a distance of about seven miles. From the end of this road a steep trail about eight miles long follows the river to Iron Mountain.

Manganese Deposits—Tubal Cain Mine.—On the northwest side of Iron Mountain manganese ore is exposed in tabular bodies about 6 feet in thickness. These bodies form a nearly continuous lode for a length of about 1,500 feet, and in places are exposed vertically for 500 feet.

Published[9] analyses show the ore averages 37 per cent manganese, 5.5 per cent iron, and 35.5 per cent silica. Native copper occurs in the bementite rock, and it was the copper that began the original exploration.

### Dosewallips River Area

The Dosewallips River flows into Hood Canal near Brinnon. This river occupies a narrow valley from the mouth to beyond the manganese deposits. The north slope of the valley forms the south slope of the ridge upon which is Mount Constance.

Manganese deposits occur in the north valley wall on Miners Creek approximately thirteen miles from the mouth of the river. On the south side, manganese ore crops out on Lucky Creek.

(9) Pardee, U. S. Geol. Survey Bull. No. 725 p. 241.

The area is reached by a road that branches from the Olympic highway and leads up the valley of the Dosewallips River.

Manganese Deposits.--Three quarters of a mile south of Corrigenda Guard Station, is an outcrop of manganese ore on the east valley wall of Lucky Creek. This outcrop is continuous for 500 feet in length, beginning at the 1,725 foot elevation. The ore body is between 2 and 3 feet in thickness. This ore is enclosed in basalt, It is reported that the ore can be traced to Mt. Jupiter, but it is more likely that outcrops of other ore bodies occur between the exposure on Lucky Creek and Mt. Jupiter.

On Miners Creek, a south-flowing tributary of the Dosewallips River, are separated exposures reported as occurring at various elevations on the slope between the road and the 5,200 foot elevation of the south slope of Mt. Constance. These outcrops are reported to be 10 or more feet in length and width. One exposure which had been opened by an open cut was examined. In this open cut ore was uncovered for little over 10 feet in length and about 6 feet in depth.

## North Fork Skokomish River Area

Several deposits occur on tributaries of the North Fork Skokomish River and range from four and one-half to eleven miles northwest of Lake Cushman. The Triple Trip and Apex deposits occur on Boulder Creek, which flows into the North Fork Skokomish River about four miles above Lake Cushman. Some additional deposits are reported as occurring south of the northwest end of Lake Cushman. A road extends from Hoodsport past Lake Cushman and for several miles up the North Fork of the Skokomish River.

Manganese Deposits--Triple Trip, Apex, and Black and White Mines.--The outcrops of manganese at the Triple Trip mine occur on Boulder Creek about one-half mile from its confluence with the North Fork Skokomish River. Exploration has been by open cut and adit levels.

One ore body has been explored that ranges between 1 and 4 feet in width and at least 50 feet in length. Both bementite and the oxide minerals occur. Up Boulder Creek from this body for a distance of about a quarter of a mile, similar outcrops have been exposed in trenches and open cuts.

Pardee[9a] reports that six samples said to be representative of the lode explored by the adits ranged from 6 to 25 per cent manganese, 21 per cent iron, 11 to 37 per cent silica, and 4 to 36 per cent lime. One sample that was analyzed for phosphorus and sulphur showed only traces.

About one-half mile up Boulder Creek from the Triple Trip are the exposures on the Apex property. These exposures are reached by a steep trail from the Triple Trip mine. Natural outcrops show one lode to be at least 30 feet wide in one place and at least 50 feet in length and

(9a) Pardee, op. cit. p. 236.

depth. The layer of bementite rock is reported to be at least 10 feet wide by Pardee[10]. Other exposures below the Apex mine show outcrops of similar material along the strike of the mineralized zone.

According to Pardee, one sample across the outcrop for a distance of 6 feet carried 33.39 per cent metallic manganese, 8.85 per cent metallic iron, 3.87 per cent lime, and 19.81 per cent silica. The ore consists of bementite and manganese oxides.

Six miles north of the Triple Trip mine, on the divide east of the North Fork Skokomish River, is the Black and White mine. This deposit is reached by trail a distance of ten miles from the Triple Trip mine. The mine is at an elevation of 4,400 feet.

Development consists of a 200-foot tunnel, a 40-foot shaft, and several pits and open cuts. About 100 tons of ore were shipped to the Bilrowe Alloys Company of Tacoma as copper ore. The lode consists mainly of bementite rock containing small flakes of native copper.

An average sample across 8 feet of the lode contained 22.81 per cent metallic manganese, 8.66 per cent iron, 0.706 per cent lime, and 24.35 per cent silica according to Pardee[11]. The operators report that other samples range from 16 to 38 per cent manganese, 2 to 11 per cent iron, 17 to 38 per cent silica, and a trace to 3 per cent lime.

Near the Black and White mine are several deposits which are said to be similar to that body. This area should prove to be a fertile field for future prospecting.

### Steel Creek Area

Ore bodies occurring on what is known as the Steel Creek group, are located in T. 23 N., R. 6 W. The outcrops occur on the valley wall of Steel Creek, a tributary of the South Fork of the Skokomish River. The Steel Creek group is reached by road following the Skokomish and South Fork Skokomish Rivers for six or seven miles. From the end of this road, a trail follows the northeastern side of the South Fork of the Skokomish River. This trail is crossed by Steel Creek some twenty miles from the end of the road. Up Steel Creek, a trail is traversed for about three miles to the deposits.

Manganese Deposits.--Several claims are included in this group. An ore body on the Bosnia claim is reported by Pardee to be 200 feet long, 8 to 10 feet wide, and to have a vertical extent of 100 feet. Several other outcrops in the area are from 10 to 15 feet wide and as long as 50 feet. Several analyses reported by Pardee averaged 24 per cent manganese, 10.5 per cent iron, and 30 per cent silica. The bementite bodies are similar to those of the North Fork Skokomish area.

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(10) Pardee, op. cit. p. 237.
(11) Pardee, op. cit. p. 239.

## Quinault Area

Deposits in this area occur in a belt approximately two miles wide and about eight miles long. This belt is mainly east of the Olympic highway and extends from Lake Quinault to about half way to the town of Humptulips. In this belt, manganese silicate rock outcrops in a score of places. Most of these outcrops are found in western tiers of Sections in T. 22 N., R. 9 W. Forest roads and trails lead from the Olympic highway to the deposits.

Manganese Deposits.--The Stevens Creek deposits are at an elevation of 790 feet in Sec. 30, T. 22 N., R. 9 W., north of the cabin on the creek. The predominant minerals are bementite and reotocite and substantial amounts of manganese oxide. This deposit occurs at the top of, and embedded in greenstone.

At an elevation of 1,150 feet on the bluff forming the west flank of the north fork of Stevens Creek there is exposed an outcrop of manganese ore occurring between greenstone and red limestone. The mineralization here is predominantly bementite.

Near the center of Sec. 30, T. 22 N., R. 9 W., at an elevation of 1,300 feet field work exposed an outcrop on one of the Old Star claims. The principal mineral is bementite. Following the trail to the crest of the ridge in the north half of Sec. 30, T. 22 N., R. 9 W., at an elevation of 1,470 feet in bluffs facing north, an outcrop of manganese ore is exposed. The deposit occurs in contact with greenstone; underlying the greenstone is a dark red limestone. The contact between the two rocks is not easily determined due to the depth of debris. Here again the ore is bementite and oxides.

The manganese ore exposed from Stevens Creek to the summit of the divide between Stevens and Skunk Creeks has a north-south trend. The several exposures may be on one continuous ore body. However, the general trend of outcrops in the entire area is about N30°E.

Exploration of manganese deposits in the Skunk Creek region consisted in trenching around an outcrop that had been prospected by a short tunnel about twenty years ago. Float lying on the hillside, which is covered by overburden, indicated the possibility of underlying deposits. The ore is principally bementite and oxides quite similar to the exposures on the Stevens Creek drainage.

On the north side of the divide between Skunk Creek and Cook Creek, in the southeast quarter of Section 19 are deposits of manganese. The deposits are composed principally of bementite. The mineral is found at the base of an overlying band of greenstone. The underlying rock is not exposed at the outcrop, but farther down the trail red limestone outcrops. This deposit was prospected some years age by a short tunnel, exposing ore, some of which is piled on the dump. Approximately 600 feet northeast is another small outcrop at the base of the same greenstone bluff.

On the south side of Cook Creek is an outcrop of manganese ore at an elevation of 1,170 feet. This deposit occurs at the top of and enclosed in greenstone. The ore mineral is principally bementite with lesser amounts of rhodonite. It is hard and resists weathering more so than the surrounding greenstone.

In the NE ¼ of the SW ¼ of Sec. 20, T. 22 N., R. 9 W., is an outcrop of manganese ore which has been exposed by a tunnel. This deposit is bementite occurring in greenstone and at an elevation of approximately 1,250 feet.

## METHODS OF TREATMENT

Imports of manganese ore are the oxides whose treatment for the recovery of manganese is relatively simple. Domestic production is mainly from the oxides with a minor amount from the carbonate and a very minor amount of the silicate.

Consumers of manganese in the steel and alloy industries use ferromanganese or spiegeleisen, both containing manganese in the oxide form. Use of elemental manganese in these major industries would require considerable changes in methods now in use.

The Olympic Peninsula manganese is chemically combined with silica and oxygen. At least in the surficial ore, manganese silicate minerals predominate over the oxides. Treatment of the silicate minerals require breaking the bond between the manganese and silica. The manganese must be removed and then deposited. It has been only in recent years that the Olympic Peninsula deposits were considered to be of commercial size. Several individual workers attacked the problems of recovering the manganese silicate minerals.

In the following pages several methods of recovery are briefly outlined without comment.

### SULPHURIC ACID BAKING - ROASTING, AND LEACHING[12]

1. Mix thoroughly approximately 30° Be. sulphuric acid with manganese ore ground to 100 mesh. 20 to 30 per cent excess acid over that required to convert the manganese to sulphate is added to convert the calcium, iron, aluminum, magnesium, etc., to sulphates.

2. Heat to 150° C and maintain this temperature from one to three hours.

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(12) Parkman, Howard C., and Durway, Charles: "The Development of a Sulphuric Acid Baking - Roasting and Leaching Process for the Extraction of Manganese from the High-Silica Ores of the Olympic Peninsula of Washington." The State College of Washington, State Electrometallurgical Research Laboratories and Washington State Planning Council, W P A Federal Project No. 3 O. P. 65-93-832. Bulletin M. First Progress Report.

3. Heat to 200°C and maint in this temperature from two to three hours.

4. Roast four hours at 650° C, 675° C, or 700° C.

5. Agitate in water heated to about the boiling point (95° to 100° C) for one hour or less to extract the manganese sulphate.

The solution should contain in excess of 7 per cent of manganese and less than 0.1 per cent iron.

By electrodeposition, manganese metal of high purity of manganese dioxide can be recovered from the manganese sulphate solution.

## GREENE PROCESS FOR PRODUCTION OF FERROMANGANESE[13]

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. In the sintered mass the manganese is removed as small metallic globules by mechanical means.

In the second process a molten bath of ferromanganese is provided. Limestone is added to the ore as a flux. As the temperature is raised, metallic globules of manganese separate out and sink into the molten bath. A slag containing the silica, limestone, 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 pre-heated by means of burning unconsumed gases in a preheating chamber.

## PRODUCTION OF MANGANESE DIOXIDE[14]

1. Sulphurous gases are blown into either a moist mass of the ore or into a cold liquor in which the finely ground ore is suspended. Acid sulphites and sulphates are formed that can be separated from the insoluble quartz and ferric oxide (jasper).

2. Filtration and rejection of insoluble residue.

3. Filtrate containing manganese, iron, lime and silicic acid is discharged into pachuca tanks where the solution is boiled and aerated.

4. Iron, lime, and silicic acid is precipitated. Manganese remains in solution as sulphate.

5. Filtration to remove precipitate which can be treated for constituents if desired.

6. Sulphurous gases set free are injected into the burner or roaster

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(13) Greene, Albert E. "Report on Reduction of Manganese Ore."
(14) Personal communication from Westby.

gases used in decomposing the ore.

7. Regenerated sodium carbonate is added to the solution of manganese sulphate to form a flocculent precipitate of manganese carbonate.

8. Precipitate is aerated and dried as it is conveyed in a thin layer to a roaster hopper into which it is discharged.

9. Manganese carbonate heated to 680° F in a Herreschof type roaster to produce manganese dioxide.

10. Manganese dioxide is discharged into the cooling and packing department.

PRODUCTION OF METALLIC MANGANESE BY ELECTROLYSIS[15]

1. Manganese sulphate solution discharged into electrolytic cells. Manganese iron concentration maintained by adding manganese carbonate precipitated from the solution by ammonium carbonate which can be regenerated.

2. Ammonium sulphate added to solution to maintain $NH_3$: Mn ratio.

3. $SO_2$ continuously added to the cathlyte as gas, sulphurous acid, or ammonium sulphite.

4. A diaphram between the electrodes permits the continuous operation. A concentration of 15 grams of manganese per liter is necessary.

## B I B L I O G R A P H Y


| | |
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(15) Developed by S. M. Shelton, Associate Metallurgist, United States Bureau of Mines.

## ANALYSES

West of Lake Crescent Area-Sol Duc Burn Locality, Sec.19,T.30N.,R.10W.

| Sample No. | Mn | Fe | $SiO_2$ | Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 14.98 | 23.61 | 30.99 | 18 | 25.89 | 14.19 | 37.30 |
| 2 | 16.75 | 23.16 | 27.42 | 19 | 31.47 | 11.65 | 22.67 |
| 3 | 18.18 | 19.34 | 26.78 | 20 | 21.43 | 17.69 | 30.83 |
| 4 | 28.54 | 17.92 | 26.18 | 21 | 23.72 | 24.11 | 26.73 |
| 5 | 17.73 | 18.48 | 19.43 | 22 | 1.87 | 34.22 | 49.74 |
| 6 | 15.74 | 20.73 | 35.67 | 23 | 16.26 | 34.65 | 17.51 |
| 7 | 24.77 | 16.92 | 27.39 | 24 | 14.17 | 29.16 | 27.65 |
| 8 | 14.55 | 25.48 | 27.83 | 25 | 19.51 | 23.50 | 28.52 |
| 9 | 5.38 | 13.01 | 71.71 | 26 | 17.60 | 28.79 | 18.37 |
| 10 | 17.01 | 22.84 | 28.25 | 27 | 10.58 | 32.47 | 36.62 |
| 11 | 23.23 | 22.00 | 55.94 | 28 | 19.29 | 28.21 | 31.77 |
| 12 | 13.63 | 24.50 | 34.84 | 29 | 20.25 | 25.93 | 30.90 |
| 13 | 31.37 | 18.12 | 12.75 | 30 | 24.92 | 19.87 | 18.48 |
| 14 | 16.76 | 32.84 | 21.21 | 31 | 17.95 | 23.08 | 32.61 |
| 15 | 25.82 | 22.86 | 23.27 | 32 | 25.87 | 17.35 | 28.67 |
| 16 | 14.44 | 34.66 | 22.38 | 33 | 25.79 | 11.20 | 30.97 |
| 17 | 18.55 | 30.33 | 23.11 | 34 | 12.78 | 28.24 | 29.22 |

Sol Duc Burn Locality, Sec.20,T.30N.,R.10W.

| Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|
| 1 | 33.20 | 7.17 | 23.86 |
| 2 | 33.08 | 7.42 | 25.54 |

Sol Duc Burn Locality, Sec.24,T.30N.,R.11W.

| Sample No. | Mn | Fe | $SiO_2$ | Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 28.19 | 15.73 | 18.36 | 21 | 16.59 | 21.18 | 30.14 |
| 2 | 19.68 | 20.67 | 25.44 | 22 | 19.61 | 13.54 | 31.17 |
| 3 | 4.64 | 17.01 | 63.93 | 23 | 18.07 | 22.78 | 28.85 |
| 4 | 10.43 | 34.85 | 28.90 | 24 | 17.66 | 20.87 | 33.45 |
| 5 | 13.93 | 15.93 | 46.77 | 25 | 26.91 | 11.40 | 23.18 |
| 6 | 16.73 | 26.36 | 30.90 | 26 | 22.13 | 14.13 | 25.88 |
| 7 | 12.20 | 21.12 | 49.51 | 27 | 27.48 | 17.34 | 20.56 |
| 8 | 29.85 | 16.90 | 18.63 | 28 | 23.80 | 16.52 | 26.79 |
| 9 | 24.01 | 17.70 | 24.15 | 29 | 19.72 | 19.18 | 32.47 |
| 10 | 25.18 | 14.38 | 26.30 | 30 | 33.00 | 13.00 | 20.23 |
| 11 | 20.62 | 19.42 | 29.98 | 31 | 24.52 | 18.95 | 19.89 |
| 12 | 17.72 | 17.52 | 35.24 | 32 | 24.02 | 14.57 | 24.28 |
| 13 | 21.19 | 22.61 | 27.30 | 33 | 24.96 | 18.62 | 24.95 |
| 14 | 26.73 | 20.27 | 22.28 | 34 | 20.17 | 33.15 | 18.33 |
| 15 | 20.83 | 19.50 | 35.17 | 35 | 22.11 | 26.67 | 21.98 |
| 16 | 18.94 | 18.42 | 27.69 | 36. | 25.69 | 19.82 | 26.33 |
| 17 | 17.33 | 21.60 | 28.40 | 37 | 12.33 | 11.92 | 60.65 |
| 18 | 20.33 | 15.98 | 36.41 | 38 | 23.39 | 22.57 | 23.24 |
| 19 | 25.57 | 13.87 | 29.06 | 39 | 19.46 | 20.94 | 32.25 |
| 20 | 24.57 | 12.76 | 32.88 | 40 | 22.81 | 20.68 | 30.27 |

Sol Duc Burn Locality, Sec. 24, T. 30 N., R. 11 W., Cont'd

| Sample No. | Mn | Fe | $SiO_2$ | Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|---|---|---|---|
| 41 | 14.05 | 19.86 | 32.20 | 51 | 12.34 | 28.47 | 37.85 |
| 42 | 14.53 | 19.38 | 41.53 | 52 | 12.53 | 30.63 | 30.16 |
| 43 | 16.57 | 24.33 | 44.08 | 53 | 9.18 | 32.12 | 44.14 |
| 44 | 9.55 | 20.41 | 50.47 | 54 | 7.66 | 9.97 | 70.18 |
| 45 | 15.27 | 22.15 | 46.52 | 55 | 10.92 | 35.43 | 42.87 |
| 46 | 15.63 | 23.86 | 35.02 | 56 | 17.09 | 37.60 | 29.28 |
| 47 | 16.36 | 20.74 | 34.50 | 57 | 25.00 | 27.00 | 24.92 |
| 48 | 13.73 | 20.30 | 33.76 | 58 | 15.51 | 30.12 | 26.66 |
| 49 | 13.56 | 25.25 | 38.29 | 59 | 15.85 | 56.82 | 17.49 |
| 50 | 12.36 | 28.62 | 35.83 | 60 | 17.38 | 34.87 | 35.57 |

Sol Duc Burn Locality, Sec.21,T.30N.,R.10W.

| Sample No. | Mn | Fe | $SiO_2$ | Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 34.80 | 14.32 | 17.73 | 5 | 40.74 | 8.56 | 9.07 |
| 2 | 34.50 | 6.68 | 17.22 | 6 | 26.38 | 7.45 | 32.40 |
| 3 | 32.20 | 19.47 | 13.54 | 7 | 27.02 | 8.59 | 30.04 |
| 4 | 32.60 | 9.61 | 25.88 | 8 | 36.25 | 6.78 | 29.09 |

Sol Duc Burn Locality, Sec.20,T.30N.,R.11W.

| Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|
| 1 | 9.59 | 11.96 | 44.24 |
| 2 | 6.84 | 12.43 | 44.88 |

Sol Duc Burn Locality, Sec.21,T.30N.,R.11W.

| Sample No. | Mn | Fe | $SiO_2$ | Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 15.70 | 29.69 | 25.51 | 15 | 23.54 | 16.49 | 28.28 |
| 2 | 13.71 | 18.50 | 41.51 | 16 | 22.68 | 14.44 | 28.95 |
| 3 | 30.92 | 17.79 | 23.51 | 17 | 24.66 | 16.01 | 29.94 |
| 4 | 20.88 | 22.17 | 29.01 | 18 | 23.35 | 19.90 | 28.87 |
| 5 | 21.25 | 21.85 | 29.59 | 19 | 18.51 | 19.74 | 46.72 |
| 6 | 21.96 | 20.00 | 30.00 | 20 | 21.19 | 14.40 | 36.59 |
| 7 | 17.40 | 26.28 | 23.97 | 21 | 19.02 | 14.95 | 37.75 |
| 8 | 22.77 | 21.51 | 29.95 | 22 | 24.74 | 16.62 | 30.07 |
| 9 | 5.57 | 27.32 | 29.08 | 23 | 1.84 | 19.62 | 67.53 |
| 10 | 20.16 | 19.05 | 32.38 | 24 | 14.65 | 20.48 | 46.12 |
| 11 | 23.35 | 13.22 | 32.01 | 25 | 18.85 | 23.20 | 37.94 |
| 12 | 28.17 | 8.90 | 35.12 | 26 | 15.73 | 23.76 | 34.73 |
| 13 | 17.55 | 10.69 | 58.54 | 27 | 32.22 | 15.63 | 17.17 |
| 14 | 24.77 | 16.92 | 27.39 | 28 | 32.49 | 16.06 | 16.59 |

Sol Duc Burn Locality, Sec.23,T.30N.,R.11W.

| Sample No. | Mn | Fe | $SiO_2$ | Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 16.51 | 17.87 | 34.60 | 5 | 23.32 | 13.67 | 38.13 |
| 2 | 19.64 | 14.63 | 44.85 | 6 | 30.85 | 12.56 | 30.01 |
| 3 | 39.80 | 19.11 | 37.92 | 7 | 19.77 | 11.69 | 31.59 |
| 4 | 28.63 | 21.75 | 40.76 | 8 | 30.00 | 14.09 | 31.47 |

Bear Creek Locality, Sec. 16,T.30N.,R.12W.

| Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|
| 1 | 41.84 | 3.21 | 13.68 |

Little River Area-Sec. 20, T. 29, R. 6 W.

| Sample No. | Mn | Fe | $SiO_2$ | Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|---|---|---|---|
| 1 | 13.84 | 13.02 | 53.59 | 12 | 3.47 | 10.91 | 74.07 |
| 2 | 25.06 | 12.14 | 50.85 | 13 | 12.21 | 16.58 | 47.23 |
| 3 | 10.97 | 13.51 | 60.66 | 14 | 6.73 | 6.04 | 77.97 |
| 4 | 8.91 | 25.33 | 31.84 | 15 | 25.8 | 15.2 | 34.1 |
| 5 | 8.86 | 23.55 | 34.73 | 16 | 13.2 | 8.4 | 68.3 |
| 6 | 8.83 | 16.08 | 43.88 | 17 | 25.2 | 5.2 | 43.7 |
| 7 | 12.21 | 18.96 | 48.60 | 18 | 17.4 | 15.0 | 22.8 |
| 8 | 9.92 | 13.48 | 63.88 | 19 | 6.6 | 11.2 | 15.2 |
| 9 | 8.51 | 13.88 | 62.61 | 20 | 34.2 | 9.2 | 19.2 |
| 10 | 21.60 | 9.28 | 50.75 | 21 | 30.6 | 6.2 | 34.2 |
| 11 | 10.81 | 9.33 | 65.63 | | | | |

Dosewallips River Area, Sec.30,T.26N.,R.2W.

| Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|
| 1 | 25.2 | 6.1 | 30.6 |

Quinault Area - Pride and Kainber Claims

| Sample No. | Mn | Fe | $SiO_2$ |
|---|---|---|---|
| 1 | 24.51 | 17.58 | 44.14 |
| 2 | 27.58 | 24.95 | 23.81 |