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MANGANESE-BEARING DEPOSITS NEAR LAKE CRESCENT AND HUMPTULIPS WASHINGTON

BY

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MANGANESE-BEARING DEPOSITS NEAR LAKE CRESCENT AND HUMPTULIPS, WASHINGTON

By J. T. PARDEE

SUMMARY

The Crescent mine, situated a short distance west of Lake Crescent, in the Olympic Mountains of Washington, yields an unusually high grade of manganese ore, which is suitable for making steel. Several manganiferous lodes of promising appearance have been found in the same area, and some near Humptulips, on the south side of the mountains. These and deposits on Skokomish River and at other places in the Olympic region are distributed around three sides of the mountains through a distance of 110 miles.

The characteristic and generally the most abundant manganese mineral in this belt is bementite, a silicate of manganese that is rare elsewhere. Hausmannite, a suboxide of manganese (Mn_3O_4) that is also rather uncommon, occurs in several of the deposits and is locally abundant in the Crescent mine, where it forms the most valuable constituent of the ore. In addition more or less of a manganiferous carbonate is present, and bodies composed of fine-grained quartz and iron oxides form a large but separate part of the lodes.

The deposits are associated with an impure red limestone of marine origin, which is probably to be correlated with the Franciscan formation of California. The limestone is overlain by a thick series of basaltic flows and tuff of Tertiary age that are partly altered to greenstone. The manganese is thought to have been deposited originally with the limestone as a carbonate. The concentration and change of much of it from the carbonate into bementite and hausmannite are believed to have been caused by warm solutions charged with silica that were expressed from the lavas or their magma. Afterward mountain-building movements and erosion elevated and exposed the manganiferous beds.

The beds at the horizon of the manganiferous deposits are very incompletely explored and are to be regarded as the possible source of large quantities of ore.

INTRODUCTION

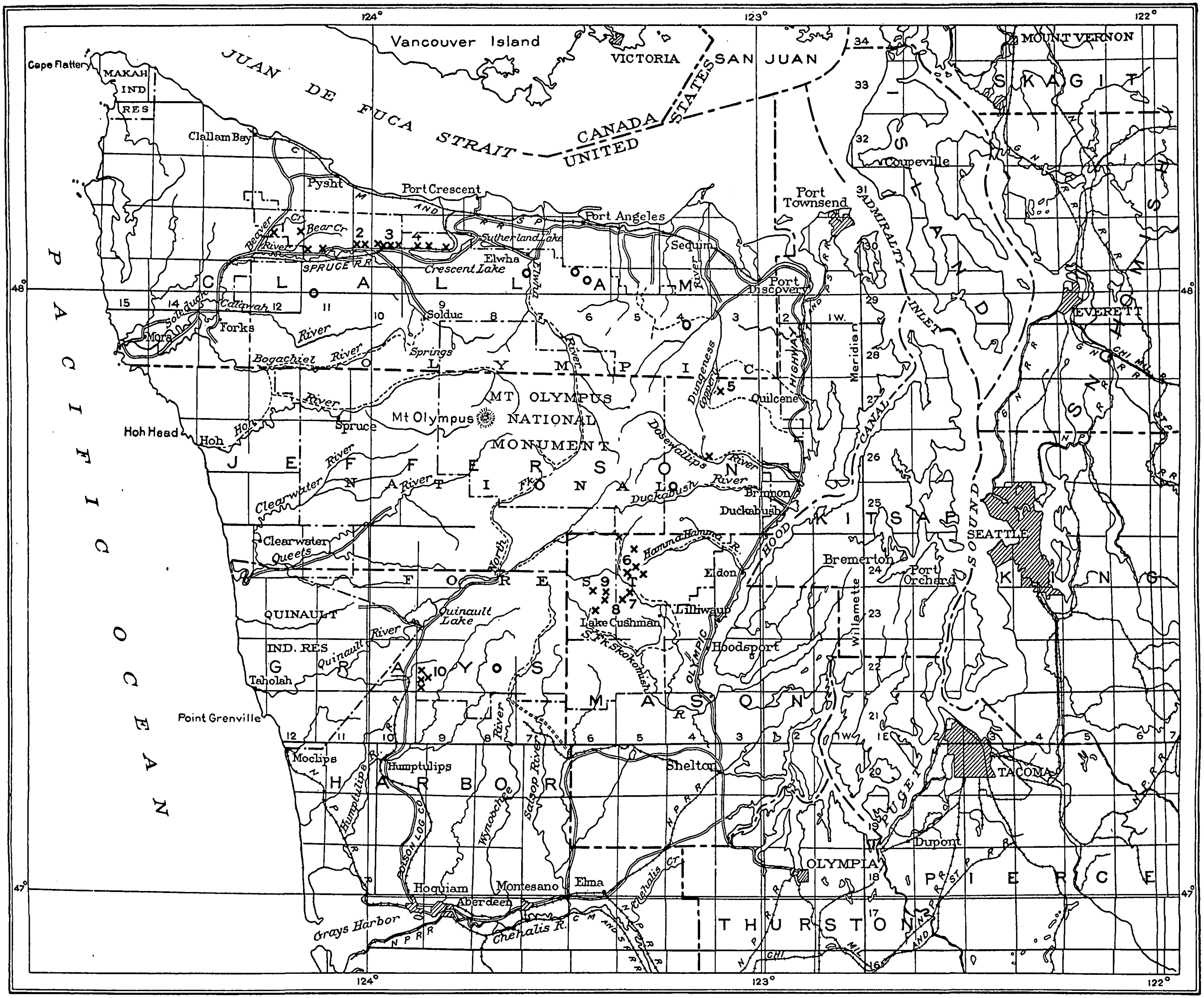
The Crescent mine is on a recent outstanding discovery of manganese ore near Lake Crescent, in the Olympic Mountains of Washington. (See pl. 1.) Before this deposit was found the Olympic Mountains were known [1] to contain large amounts of manganiferous material, but the known deposits were composed chiefly of bementite, a silicate of manganese not usable under existing conditions. The ore of the Crescent mine is a high-grade oxide suitable for use in making steel, and its occurrence greatly encourages the belief that usable ore will be found in other parts of the extensive manganiferous belt of the Olympic Mountains. In addition to the Crescent deposits, recent discoveries include several promising outcrops in the Lake Crescent area and near Humptulips, on the south side of the mountains.

A short visit to the Crescent mine and the neighboring prospects and to the prospects near Humptulips was made by the writer in August, 1925. Earlier in the season these deposits had been inspected by J. W. Furness, of the Bureau of Mines, to whom the writer is indebted for much information. Acknowledgment is also gratefully made to Messrs. Jamison & Peacock, operators of the Crescent mine, for information and courtesies extended in the field. A large share of the credit for the preparation of this report is due to Clarence S. Ross, of the United States Geological Survey, who made the optical determination of minerals composing the manganiferous lodes and the associated rocks. Owing to the generally fine texture and mixed habit of the materials, this work was unusually difficult. It was supplemented with chemical tests made in the laboratory of the Geological Survey by J. G. Fairchild and E. P. Henderson. Unmixed material for some of the analyses was selected microscopically by M. N. Short.

ACCESSIBILITY

The Crescent mine is in Clallam County, only a short distance from the Olympic Highway at a point about 1½ miles west of Lake Crescent and 25 miles west of Port Angeles. From the highway a road extends north to an ore bin at the foot of a steep slope below the workings of 1925. The bin is connected with the mine by an aerial tramway 1,400 feet long, designed for transporting ore, and by exercising due caution persons may safely ride on it. There is also a foot trail from the highway to the workings, the vertical ascent being about 750 feet. The railroad built by the Government during

[1] Pardee, J. T., Deposits of manganese ore in Montana, Utah, Oregon, and Washington: U. S. Geol. Survey Bull. 725, pp. 234–235, 1921; Bementite and neotocite from western Washington; Washington Acad. Sci. Jour., vol. 11, pp. 25–32, 1921.



Scale $\frac{1}{1{,}000{,}000}$

10 0 10 20 30 40 Miles

MAP SHOWING DISTRIBUTION OF THE MANGANIFEROUS DEPOSITS NEAR LAKE CRESCENT AND HUMPTULIPS, WASH.

1, State Lease; 2, Ed B.; 3, Crescent; 4, Mother Lode; 5, Tubal Cain; 6, Black and White; 7, Triple Trip; 8, Apex; 9, Steel Creek; 10, Star the war to obtain spruce timber and later sold to Lyon & Hill extends along the foot of the slope past the ore bin and has transported the ore to the seaboard at Port Angeles. Most of the other deposits near Lake Crescent are within a mile or two of the highway and the railroad, and are reached by trails.

The prospects near Humptulips, in Grays Harbor County, are about 1½ miles from the branch of the Olympic Highway that extends from Hoquiam to Lake Quinault. They are reached over a trail that leaves the highway at a point about 35 miles from Hoquiam, 10 miles beyond Humptulips, and within 6 miles of the lake. A railroad of the Polson Logging Co. from Hoquiam passes within a mile or two of these prospects.

The portion of the manganiferous belt distant from the highways above mentioned is difficult of access. There are few trails suitable for horses, and progress on foot is painfully slow and laborious, owing to the excessively steep slopes, the litter of huge fallen logs, and the dense undergrowth.

SETTLEMENTS, INDUSTRIES, VEGETATION, AND CLIMATE

There are no settlements within the manganese-bearing zone; a few forest-ranger stations and several tourist hotels at Lake Crescent and other delightful sites are almost the only habitations. The region, however, is visited by many tourists, who are attracted in increasing numbers each year by the wild game and the striking scenery.

Lumbering, which for years has been working steadily back from the coast, has reached and penetrated the mountains on the north, east, and south. On the west there still remain large areas of that remarkable forest of huge fir, spruce, and other evergreen trees that is one of the wonders of the continent. Hardly less noteworthy is the beauty of the ferns and shrubs that characterize the undergrowth. At an altitude of 5,500 to 6,000 feet the forest ceases.[2] Near the timber line are tracts of open grasslands, and the higher summits are mostly areas of barren rocks, snow, and ice. In the timbered belt grasses and similar forage plants are absent, and the ground, rocks, and fallen logs are generally covered with a thick moss.

From the nature of the vegetation it is evident that the region possesses a rather cool, moist climate. Records of the United States Weather Bureau [3] show that the mean annual rainfall on the coastal

[2] Gannett, Henry, Summary of forestry work in 1899–1900: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 5, p. 13, 1902.

[3] Climatological data for the United States, Summary, sec. 19, western Washington, to 1921, inclusive.

strip north of the mountains increases westward from about 17 inches at Sequim to 67 inches at Pysht. Brinnon, on Hood Canal near the east foot of the mountains, has about 75 inches; Quinault, on the south side, 125 inches; and Forks and Clearwater, in the coastal strip west of the mountains, respectively, 122 and 128 inches. On the western slope and the higher parts of the mountains the annual precipitation doubtless exceeds the highest record given above. By far the most of the annual precipitation occurs in the period extending from September or October to April or May. On the lower slopes of the mountains and the bordering lowlands snow occasionally falls in the months from November to April, but does not remain long on the ground. In the higher mountains, as indicated by large snow and ice fields that persist throughout the year, the aggregate winter snowfall must be enormous. Temperatures are comparatively equable, and extremes and sudden changes are rare. Mean annual temperatures at the several stations named above range from 46.8° F. at Port Angeles to 50.3° at Brinnon and Quinault. The summer months are characterized by sunshine and cool breezes. At Port Angeles the recorded sunshine for the year is 45 per cent.

SURFACE FEATURES

The Olympic Mountains are a compact group of rugged peaks and ridges that occupy a roughly circular area about 50 miles in average diameter. The area is elongated somewhat toward the northwest, so that the longest diameter, which may be regarded as the main axis of the mountain mass, trends N. 50° or 60° W. On all sides the mountains present a bold front and picturesque outlines. The outer slopes rise steeply to a height of 3,000 or 4,000 feet. From this altitude the ridge summits rise more gradually toward the interior. The central mass is characterized by towering pinnacles, serrate ridges, cliff-like slopes, snow fields, and glaciers. Mount Olympus, the central and highest summit, is described as a cluster of jagged rocks projecting through an ice cap 2 miles wide and 4 miles long.[4] In view of the rather moderate altitude of these mountains, the great extent of their permanent snow and ice fields is surprising. Doubtless it can be partly explained by the heavy winter snowfall. It is needless to remark that in such a region rushing streams, waterfalls, and cascades abound on every hand.

The manganiferous deposits so far as known are confined to the outer slopes of the mountains on the north, south, and east, and for the most part are within the heavily timbered belt below an altitude of 4,000 feet. Near Humptulips they are found near the foot of the mountains between altitudes of 500 and 1,000 feet, and in the Lake

[4] Gilman, C. E., The Olympic country: Nat. Geog. Mag., vol. 7, pp. 133–140, 1896.

Crescent area between 1,000 and 3,000 feet. Topographic details of most of the Lake Crescent area are shown by the maps of the Pysht, Port Crescent, and Lake Crescent quadrangles published by the United States Geological Survey. The local relief ranges from 1,000 to 3,000 feet or more, and the land surface is mostly made up of exceedingly steep slopes. Lake Crescent occupies part of a deep valley that extends from Little River east of the Elwha westward to the coastal plain. Lake Sutherland and Soleduck River occupy other parts of the same valley that are respectively east and west of Lake Crescent, though all have independent drainage. The sides of the Lake Crescent-Soleduck valley are steep and rise abruptly from the edges of the lakes or from the narrow valley floor. The south side is formed by precipitous spurs that lead back to the central mountain mass. The north side, from the bend in Lake Crescent west to Bear Creek, a distance of about 20 miles, is a steep, straight, and narrow ridge 2,500 to 3,000 feet high with no low passes. Mount Muller, near the middle of this ridge, reaches an altitude of 3,760 feet; and Pyramid Mountain, at the east end, and Snider Peak, at the west end, are respectively 3,100 and 3,174 feet high. The lake curves around the east end of the ridge and thus assumes its crescent shape. Farther east and west the north side of the valley is formed by other steep ridges that are offset somewhat to the north of the axis of the Mount Muller ridge. Between the valley and the Strait of Juan de Fuca is a series of parallel ridges and hills whose members decrease in altitude until they sink beneath the rather narrow coastal terrace.

In the Humptulips area, as elsewhere in the Olympic Mountains, the slopes are steep and the ridges and valleys narrow.

Most intervening parts of the manganiferous belt are higher and more rugged than the Lake Crescent and Humptulips areas. At the Black and White mine, on the North Fork of Skokomish River, the altitude is 4,000 feet or more, and at the Tubal Cain mine, near Mount Constance, it is 6,500 feet.

CONDITIONS AFFECTING PROSPECTING

From the foregoing description it may be correctly surmised that prospecting in the Olympic region is unusually difficult. Not only is travel slow, but the search for outcrops is hindered by a generally thick cover of moss, which must be scraped off the rocks before their character can be ascertained. Conditions are somewhat more favorable in certain burned areas, of which the "big burn" west of Lake Crescent is the largest. There an area 10 or 12 miles long and 2 miles wide on the southward-facing slope of the Mount Muller ridge was burned so completely several years ago that natural reforestation has not yet taken place. Most of the prospects so far discovered in the Lake Crescent region are in this burn.

Within the unburned forest natural exposures of bare rock are practically confined to stream channels and cliffs or sharp-crested ridges. Most of the streams have steep gradients, and therefore flow upon bedrock. Owing to this fact a few deposits of manganese-bearing rock have been discovered that were exposed in place in the stream channel. Other outcrops have been located by the usual method of tracing to their source loose fragments or "float" found in the streams. Near Humptulips this method is rather easily applied, but in the Lake Crescent area it is more or less uncertain and difficult, because much of the "float" has been removed or shifted out of place by glaciation.

GEOLOGY

STRATIGRAPHY

The geology of the central part of the Olympic Mountains is almost unknown. Weaver[5] describes some of the high ridges leading up to Mount Olympus as composed of quartzite and slate, probably of Paleozoic or Mesozoic age. Diller[6] states that a large part of these mountains is composed of a series of metamorphic sandstone, shale, radiolarian chert, serpentine, and other rocks that closely resemble the Franciscan formation of the Coast Ranges of California. Except some dikes of diabase or diorite, granitic intrusive rocks have not been observed.

The manganiferous belt is underlain by a sedimentary series made up of sandstone, shale, and limestone, of which the bedding is rather indefinite and the structure obscure. Above this series is a great thickness of more or less altered basic lavas, collectively referred to herein as greenstone. Throughout the belt the sedimentary series is of constant character, as illustrated by the fact that specimens collected near Humptulips, on Skokomish River, and in the Lake Crescent area can hardly be distinguished from one another. The sandstone is a dull-gray strongly cemented arkose without distinct bedding. Commonly it shows many small flakes of white mica, and under the microscope it is seen to be composed chiefly of clastic grains of quartz and partly decomposed feldspar. The rocks called shale include argillite and slate. They range from dull gray to almost black.

In their general make-up the sedimentary rocks of the manganiferous zone are similar to comparable members of the Franciscan

[5] Weaver, C. E., The Tertiary formations of western Washington: Washington Geol. Survey Bull. 13, p. 65, 1916.

[6] Diller, J. S., The relief of our Pacific coast: Science, new ser., vol. 41, p. 55, 1915; Guidebook of the western United States, Part D, The Shasta Route: U. S. Geol. Survey Bull. 614, p. 13, 1915.

formation of California, which includes arkosic sandstone and foraminiferal limestone,[7] and are doubtless to be correlated with them.

The limestone forms only a small part of the sedimentary series, but it is of especial interest because of its close and characteristic association with the manganiferous deposits. It occurs in nonpersistent lenslike bodies, most of which are less than 100 feet thick. Representative specimens are a very fine grained, dense, dark maroon or chocolate colored rock with a splintery or conchoidal fracture. Commonly the rock shows irregular threads and veinlets of white calcite, and the weathered surface is coated with a brownish-red powder composed chiefly of iron oxide. In places it grades into shale. Microscopic examination by Clarence S. Ross of specimens from the Lake Crescent area show the rock to be made up of small spherical aggregates of carbonate embedded in very fine claylike material mixed with dark-red metallic oxides. Qualitative chemical tests indicate the presence of calcium carbonate, iron oxides, silica, and manganese. The composition of a representative sample is as follows:

Partial analysis of red limestone from Lake Crescent, Wash.

[Analyst, J. G. Fairchild]

Manganous oxide (MnO) (manganese 6.60)	8.52	Silica (SiO_2)	11.53
Magnesia (MgO)	3.03	Alumina (Al_2O_3)	6.18
Lime (CaO)	31.70	Iron oxide (Fe_2O_3)	7.95
Carbon dioxide (CO_2)	24.42	Titanium oxide (TiO_2)	.60
		Phosphorus pentoxide (P_2O_5)	.40

The analysis shows insufficient carbon dioxide present to satisfy all the lime, magnesia, and manganese as carbonates. Therefore part of these bases is probably combined as silicates.

Foraminifera were recognized in specimens of the red limestone from the Lake Crescent and Skokomish River areas. Those from Skokomish River were determined by T. W. Stanton as most probably belonging to the genus *Globigerina*, which may indicate that the rock is Mesozoic or younger.[8]

The rocks called greenstone comprise a group of basaltic flows, tuffs, and dikes, the bulk of which is evidently later than the red limestone. These rocks are massive and generally without structure other than the numerous fractures and slip planes caused by severe deformation. They are mostly dark greenish gray with small spots and streaks of white, which represent secondary minerals filling

[7] Lawson, A. C., U. S. Geol. Survey Geol. Atlas, San Francisco folio (No. 193), 1914; Davis, E. F., The radiolarian cherts of the Franciscan group: California Univ. Dept. Geology Bull., vol. 11, p. 240, 1918.

[8] Pardee, J. T., Deposits of manganese in Montana, Utah, Oregon, and Washington: U. S. Geol. Survey Bull. 725, p. 232, 1921.

cavities and cracks. The microscopic features of representative specimens determined by Mr. Ross are as follows:

Specimen C–49, from exposure along Olympic Highway on the north shore of Lake Sutherland. A rather fine grained basalt with groundmass crystals averaging about 0.3 millimeter in length and sparse phenocrysts of plagioclase and augite about 1 millimeter in length. The groundmass is composed of lath-shaped calcic plagioclase and augite about half as abundant as the plagioclase. Part of the augite forms nearly equiangular grains, and part of it radial groups of crystals. The augite is nearly fresh, but the plagioclase has been partly altered and now contains much sericite-like material. The rock was originally vesicular, and the cavities are now filled with calcite, zeolites, and a little chlorite.

Specimen P–1, from outcrop along trail west of the Crescent mine. A basaltic tuff composed of fragments as much as 3 millimeters in diameter. The rock grains are all basaltic and have about the composition of specimen C–49. The texture of the grains differs greatly; some are rather coarse basalts, and others are fine grained or have a glassy matrix. Associated with the rock fragments are mineral grains of calcic feldspar, augite, some olivine, and analcite that formed before the explosive fragmentation of the rock. Secondary minerals present are sparse zeolites and chlorite. The rock as a whole is nearly fresh, and only the fine-grained and glassy interstitial material is greatly altered.

Specimen C–28, from an open cut on the Mother Lode claim, north shore of Lake Crescent. Forms the hanging wall of a manganiferous deposit. A fine-grained basalt with plagioclase phenocrysts in a groundmass characterized by plagioclase and augite. These are inclosed in a matrix of secondary material that probably represents devitrified glass. The rock contains a much smaller proportion of augite than specimen C–49, and the minerals are more altered. The rock was not vesicular but now contains veinlets of a zeolite that is probably laumontite.

Other specimens are of similar composition. A few show a coarse texture suggesting an intrusive body. Greenstones like those described are abundant near Humptulips and in the Skokomish River area.

Most if not all of the greenstone described appears to belong to a group of basaltic flows and tuffs that surround the Olympic Mountains on the north, south, and east, and are described by Weaver [9] and others. These rocks overlie a series of Mesozoic rocks, are more or less altered to greenstone, and are interbedded with sediments containing upper Eocene fossils.

The Eocene series is about 4,000 feet thick. It dips away from the mountains and at the north passes beneath great thicknesses of Oligocene, Miocene, and Pliocene sediments, which in turn are overlain by Pleistocene glacial drift and alluvium.

STRUCTURE

Owing to the indistinct bedding and general absence of contrasting features in the rocks of the manganiferous belt, the struc-

[9] Weaver, C. E., op. cit., pp. 81–163.

ture is difficult to make out. It is evident, however, that the general strike is parallel to the trend of the manganiferous belt and that the beds are steeply tilted and are displaced by faults. The Mount Muller ridge in the Lake Crescent area has an east-west strike. Several neighboring parallel ridges probably strike in the same direction. Near Humptulips and in the Skokomish River area the general strike is northeast. The repetition of similar outcrops observed along the Skokomish suggests a series of close folds or strike faults. The net result of the structure, however, is to carry the series downward away from the mountains.

Between Lake Crescent and the Strait of Juan de Fuca the Tertiary rocks are bent into a large syncline that trends northwest. South of this trough and west of the Lake Crescent area the structure is complex along a line referred to by Arnold[10] as the axis of the Olympic Mountains, that extends toward Cape Flattery.

GLACIATION

In Pleistocene time the central part of the Olympic Mountains was covered by an ice cap from which glaciers descended the valleys leading out on all sides. Those on the south and west reached the plain at the foot of the mountains. Those on the north and east were held back by continental ice from the north, which filled the valleys of Puget Sound[11] and the Strait of Juan de Fuca. The continental ice, together with the mountain glaciers, filled the Lake Crescent-Soleduck valley to an unknown but considerable depth. Moraines left by the ice clog the valley at both ends of Lake Crescent, forming the present hummocky divides, and outwash gravel forms the flats along Soleduck River. The area of manganiferous prospects near Humptulips was not glaciated, but ice filled the valley of Quinault River near by and deposited a moraine at the foot of Lake Quinault.[12]

MANGANIFEROUS DEPOSITS

DISTRIBUTION

Deposits of manganese minerals are known to occur around the south, east, and north sides of the Olympic Mountains from the neighborhood of Humptulips to Beaver Creek, west of Lake Crescent, a distance of 110 miles. At the southwest end of this belt are the prospects near Humptulips described herein. Between these and

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[10] Arnold, Ralph, Coal in Clallam County, Wash.: U. S. Geol. Survey Bull. 260, p. 416, 1905.

[11] Bretz, J. H., Glaciation of the Puget Sound region; Washington Geol. Survey Bull. 8, pp. 32–34, 221–222, 1913.

[12] Lupton, C. T., Oil and gas in the western part of the Olympic Peninsula, Wash.: U. S. Geol. Survey Bull. 581, p. 36, 1915.

the South Fork of Skokomish River is a 20-mile stretch in which manganiferous "float" has been reported, but no further information about the deposits has been obtained. Between Skokomish River and Mount Constance, a distance of 25 miles, are a number of well-known deposits, including the Black and White, Triple Trip, Tubal Cain, and others described in a former report.[13] From Mount Constance to Lake Crescent is a 40-mile stretch in which a few manganiferous outcrops have been reported. The remainder of the belt from Lake Crescent to Beaver Creek, about 25 miles long, is marked by well-distributed outcrops, including that of the Crescent mine.

OCCURRENCE AND CHARACTER

The manganiferous deposits are closely associated with a marine limestone of probable Mesozoic age, which is part of a thick series comprising strongly deformed and partly metamorphosed sediments and some volcanic rocks. Above this series is a great thickness of partly altered basaltic lavas regarded as early Tertiary. The limestone and the manganiferous deposits dip outward around the flanks of the mountains and pass beneath the surface. Toward the northeast, on the opposite side of Puget Sound, they apparently rise again, as indicated by the occurrence of characteristic deposits at Fidalgo Island and Samish Bay.[14] The meager geologic information available indicates that toward the interior of the mountains the manganiferous deposits have been eroded away.

The manganiferous deposits are tabular or lenslike bodies that lie parallel to the strike of the inclosing rocks. They range from a foot or less to 20 or 30 feet in thickness, and from a few feet to several hundred feet in their other dimensions. Many of them grade indefinitely into the associated limestone, but they are sharply separated from the other kinds of country rock, chiefly greenstone, with which they are in contact. As a rule they are dense, compact bodies, without structure other than jointing, except that in places they show an indistinct banding or mottling suggesting the structure of a rock that they have replaced. Except in very thin layers along seams and joint planes, weathering has not altered the deposits more than a foot or two below the surface.

MINERALOGY

Most of the lodes are made up of two distinct parts, one of which consists almost wholly of silica and iron oxides in various proportions, and the other is composed chiefly of manganese minerals. The siliceous part is present in most of the lodes in the Skokomish

[13] Pardee, J. T., op. cit., pp. 236–243.
[14] Idem, p. 242.

River area, where it consists of fine-grained quartz and hematite.[15] Rather curiously, the siliceous part was not observed in the Crescent deposit, but it is present in all the other lodes that were examined in the Humptulips and Lake Crescent areas. Specimens representing the deposits in those areas have been determined microscopically by Clarence S. Ross to consist chiefly of quartz, which "occurs in the form of equant grains and as veinlets and radial groups that resemble a coarse type of chalcedony. This type of quartz was probably formed from solution at no great depth below the surface. Some that occurs in cracks was evidently precipitated directly from solution, but the rest may have replaced an older material." Commonly the quartz is stained brown, red, or yellow with finely divided iron oxides in various amounts. Locally hausmannite is present. Some specimens show rounded areas of lighter shades in a dark groundmass suggesting oolitic grains. Some are cut by veinlets of calcite or of manganiferous carbonate. In a specimen from the Star No. 3 claim near Humptulips the original rock is completely replaced by silica, but retains a structure that somewhat resembles that of a rhyolitic volcanic flow.

The manganiferous part of the lodes is characterized by silicates, of which the most abundant is bementite, a mineral that so far as known is rare in other parts of the world. Bementite from deposits on the North Fork of Skokomish River has the formula $8MnO.5H_2O.7SiO_2$ and contains theoretically about 35 per cent of silica and 31 per cent of metallic manganese.[16] It is a tough light-gray or grayish-brown mineral that has a vitreous luster, a splintery fracture, a hardness of about .6, and a specific gravity of about 3.1, is easily fusible to a black glass, and is decomposed by hot acids. It is transparent in splinters, but upon weathering becomes dull and opaque. The microscope shows it to be as a rule an extremely fine grained felted aggregate of fibers and plates. In most of the deposits in the Skokomish River area bementite predominates over other constituents of the manganiferous bodies to such an extent as to give its character to the whole. Weathering causes the bementite rock to darken and finally become black, owing to the production of a soft, amorphous dioxide of manganese, but this product is present in quantities so small as to be of little or no economic importance. Locally the bementite rock is cut by veinlets, visible to the unaided eye, that contain one or more of the minerals quartz, calcite, manganocalcite, rhodonite (pink silicate of manganese), rhodochrosite (manganese carbonate), and manganophyllite (manganese mica), and in places disseminated specks and flakes of native copper of a later generation than the bementite are present.

[15] Pardee, J. T., op. cit., pp. 234–243.

[16] Pardee, J. T., Larsen, E. S., and Steiger, George, Bementite and neotocite from western Washington: Washington Acad. Sci. Jour., vol. 11, pp. 25–32, 1921.

The Skokomish River deposits contain relatively small amounts of neotocite, a noncrystalline silicate of manganese having the approximate chemical composition $MnO.SiO_2.nH_2O$.[17] A sample contained in round figures 37 per cent of silica and 28 per cent of metallic manganese. This mineral is brown to black and has a clear resinous luster and a conchoidal fracture. It is brittle and has a hardness of about 4.

Both bementite and neotocite were identified by Mr. Ross in specimens from the deposits near Humptulips and Lake Crescent, which he states are

very complex aggregates of carbonates, manganese oxides, silicates, and quartz. Hausmannite is the predominant mineral in most of the ore. Bementite is the next most abundant material in some specimens, and an impure manganese carbonate, probably near rhodochrosite, in others. Braunite may be present in small amounts, but it would be impossible to distinguish this mineral from the hausmannite containing disseminated bementite. Calcite is almost always present in small amounts, and is always the last mineral to form. It is evident that the manganese oxides are the result of rearrangement and replacement of the original material of the ore. These changes are so complete that the original material is not evident from the specimens. The ores as now seen may be the result merely of rearrangement of the original material rich in manganese, or they may be the result of very complete replacement by material brought from outside sources. Nonmanganiferous minerals that occur in small amounts are quartz, the zeolite thomsonite, calcite, and iron oxides.

Neotocite forms translucent, waxy, reddish-brown veinlets and patches in specimens from the Star No. 5 claim, near Humptulips, and the Mother Lode claim, near Lake Crescent.

Hausmannite is the predominant manganese mineral in ore from the Crescent mine and is more or less abundant in several of the other deposits in the Lake Crescent area and near Humptulips. A reexamination of the samples collected in the Skokomish River area in 1917 and 1918[18] has resulted in identifying hausmannite in some of those from the Triple Trip and Apex mines.

Hausmannite is a suboxide of manganese having the formula Mn_3O_4 and containing theoretically 72.05 per cent of metallic manganese. It is black and opaque, and has a hardness of about 5 and a dark-brown streak. In the ore from the Crescent mine hausmannite occurs as wavy or mammillated layers alternating with the mixed carbonate-bementite groundmass, and as veinlets cutting both; locally it forms nearly pure masses of considerable size. An analysis of a sample from one of these masses is given below.

Small quantities of the softer manganese oxides occur near the surface. Of these pyrolusite has been identified in a specimen from the outcrops on the Peggy claim. At one place in the Crescent

[17] Pardee, J. T., Larsen, E. S., and Steiger, George, op. cit., p. 18.

[18] Pardee, J. T., Deposits of manganese ore in Montana, Utah, Oregon, and Washington: U. S. Geol. Survey Bull. 725, pp. 237–238, 1921.

mine the ore is cut by thin seams and veinlets of bright-pink cinnabar. Native copper and copper minerals, which occur in the Skokomish River area and at other places in the manganiferous belt, have not been observed in either the Lake Crescent or the Humptulips area.

COMPOSITION

The ore from the Crescent mine is noteworthy for its high content of manganese, the average of several shiploads produced being more than 52 per cent. Silica, iron, and phosphorus are low. The composition of a sample representing a variety of the ore comparatively rich in hausmannite is given below, and an analysis given in a former report[19] of bementite rock from the Black and White mine in the Skokomish River area is added for comparison.

Incomplete analyses of manganiferous material from the Olympic Mountains, Wash.

	1	2
Silica (SiO_2)	7.65	23.68
Alumina (Al_2O_3)	.0	3.48
Ferric oxide (Fe_2O_3)	.94	3.52
Manganese monoxide (MnO)	73.88	46.57
Magnesia (MgO)	1.10	1.31
Lime (CaO)	5.49	1.56
Carbon dioxide (CO_2)	4.35	------
Loss on ignition	------	18.32
	93.41	98.44
Manganese (Mn)	57.22	36.08

1. Ore from Crescent mine, analyzed by J. G. Fairchild.
2. Bementite rock, analyzed by George Steiger.

So far as known to the writer no analyses of material from other deposits in the Olympic region are available. Ore much like that of the Crescent mine in appearance is present, however, in several other lodes in the Lake Crescent area, in at least one near Humptulips, and in one or two in the Skokomish area.

ORIGIN

Available information is perhaps insufficient to determine conclusively the origin of the Olympic manganese deposits. Many of the features they present are unique or uncommon. The most abundant mineral of the deposits, bementite, is almost unknown elsewhere. Hausmannite, the most valuable ore constituent, is less rare, though it is an uncommon mineral. In the United States outside the Olympic Peninsula hausmannite in noteworthy amounts is reported from only three places—in the Batesville district of Arkansas,[20] near Bro-

[19] Pardee, J. T., op. cit., p. 235.

[20] Miser, H. D., Hausmannite in the Batesville district, Ark.: Washington Acad. Sci. Jour., vol. 10, pp. 1–8, 1920; Deposits of manganese ore in the Batesville district, Ark.: U. S. Geol. Survey Bull. 734, 1923.

mide, Okla.[21] and near San Jose, Calif.[22] In those places it is associated with carbonates and other oxides of manganese. The hausmannite near Bromide and San Jose is regarded as of high-temperature hydrothermal origin. That in the Batesville district is thought to have been derived from manganese carbonate near the surface and deposited by cold meteoric waters. Except chalcedonic quartz, which suggests deposition near the surface, the other minerals of the Olympic deposits appear to have no especial genetic significance. Mixed carbonates of manganese, calcium, and other metals occur elsewhere in deposits of both deep-seated and superficial origin. Two interesting minerals, cinnabar and native copper, found in these lodes are thought to be accidental associates and not significant of the genesis. The copper is not confined to the manganiferous deposits, and the cinnabar is a small local occurrence. Both are later than the lodes, and not improbably had their sources in the volcanic series of Tertiary age.

So far as the mineralogy shows, therefore, the manganiferous deposits might have been derived from some deep-seated source by means of ascending solutions or intrusions, and thus come within the same category as metalliferous quartz lodes at Philipsburg, Butte, and other places in the Western States. This idea, however, is not supported by the geology, and in fact seems to be definitely disproved by the occurrence of the deposits at widely separated localities at the same geologic horizon. Therefore, a sedimentary origin of the manganese seems to be the most plausible hypothesis to consider at this time.

As described herein the deposits are distributed along a horizon marked by a marine limestone, which in turn is overlain by basaltic lavas. The limestone contains noteworthy amounts of manganese, and parts of it appear to have been replaced to form the manganiferous lodes.

Sedimentary deposits of manganese ore, chiefly carbonates, occur in many parts of the world. Among these the deposits at Conception and Trinity Bays, Newfoundland, described by N. C. Dale,[23] show some features that are not unlike those of the Olympic Mountains.

The Newfoundland deposits occur in an unmetamorphosed series of Cambrian sandstone, shale, and limestone in the form of layers and nodules, which are composed of mixed manganese, calcium, and

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[21] Hewett, D. F., Manganese deposits near Bromide, Okla.: U. S. Geol. Survey Bull. 725, pp. 311–329, 1921.

[22] Rogers, A. F., Occurrence of manganese minerals near San Jose, Calif.: Am. Jour. Sci., 4th ser., vol. 48, pp. 443–449, 1919.

[23] Dale, N. C., The Cambrian manganese deposits of Conception and Trinity Bays, Newfoundland: Am. Philos. Soc. Proc., vol. 54, pp. 371–456, 1915.

magnesium carbonates, with quartz, alumina, hematite, iron silicates, barite, and phosphate of lime. There is also some manganese oxide, probably MnO_2, and possibly some manganese silicate. The iron and manganese are contemporaneous, but occur generally in separate bodies. The barite, chlorite, and some calcite are of a later generation. The richer layers contain as much as 25 per cent of metallic manganese. The manganese of those deposits was derived from decompositioin of the rocks and was carried in solution by rivers to the sea. Concentration of soluble manganese silicates and bicarbonate occurred in the sea water, and the manganese was precipitated by liberation of carbon dioxide. During this process there probably occurred a migration of material or selective precipitation, which concentrated the manganese in bands and nodules. The separation of the manganese and iron may be explained as due to their different rates of oxidation and degrees of solubility.

An origin of the Olympic deposits is suggested by the known facts as follows:

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 basaltic lava, forming a thick cover over the sediment.
3. Emanation of silica as a final phase of the volcanism, the silica probably being carried in solution by circulating waters expressed from the lava or of deeper magmatic orgin.
4. Chemical reactions between the limestone and the 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 ("cap rock"). 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.

Under the hypothesis above set forth 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. Successful development of ore, when found, would depend largely on a knowledge of the structure, particularly the faulting, which should be worked out in detail.

The origin indicated suggests that on the average the ore should be as persistent down the dip as along the strike. No essential change in the character of the manganiferous bodies should be expected in depth. Rich hausmannite ore, for example, may be expected at any point.

The manganiferous horizon has been only slightly explored. Its extent and persistence make possible the occurrence of a large aggregate amount of ore, which future exploration may confidently expect to find.

MINES AND PROSPECTS

CRESCENT

The Crescent ore deposit was discovered in September, 1923, and development work was begun a few months later by Jamison & Peacock, of Duluth, Minn., the present operators. Ore production began about the middle of 1924, and up to September, 1925, it had amounted to more than 11,000 tons, most of which was shipped by the Panama Canal to Philadelphia for use in making steel.

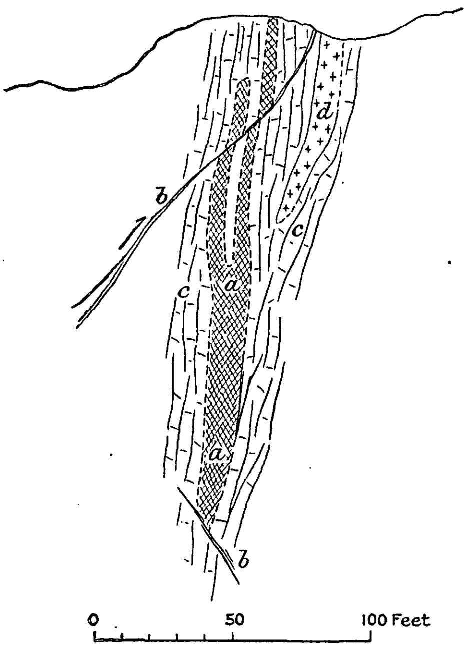
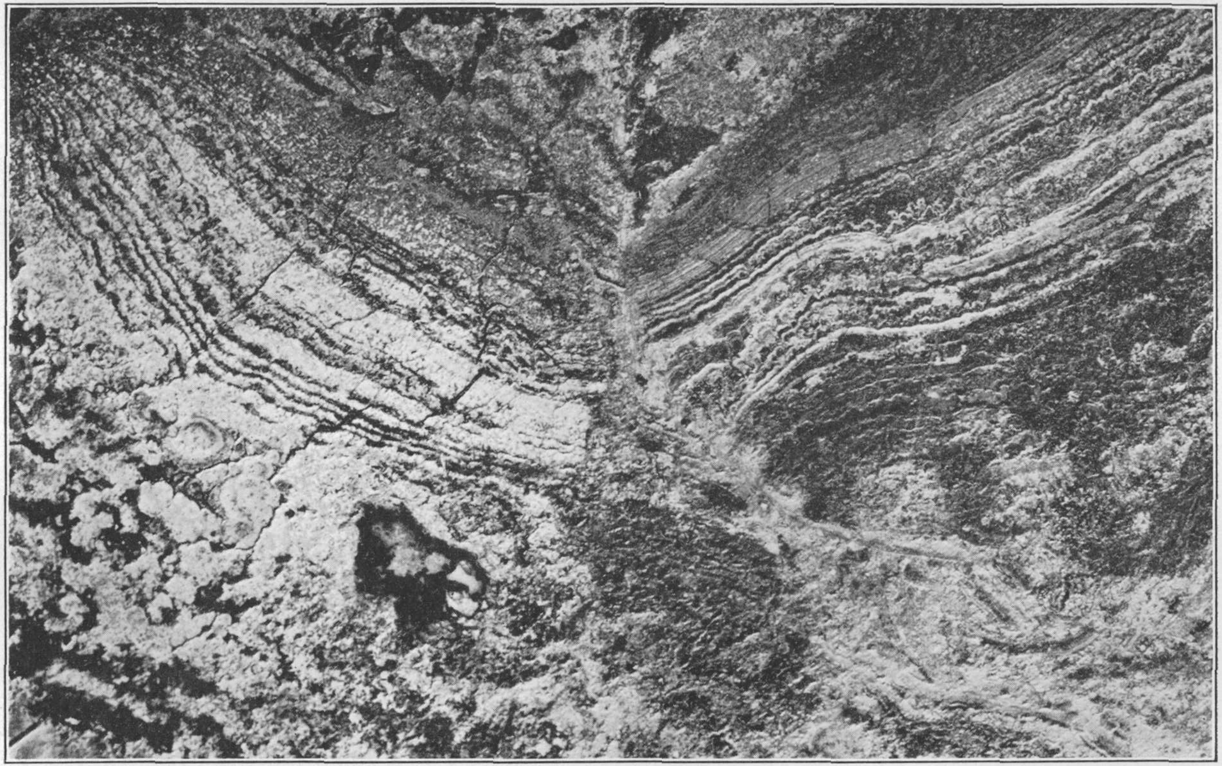


FIGURE 1.—Vertical cross section of ore body in the Crescent mine, near Lake Crescent, Wash. *a*, Ore; *b*, thrust fault; *c*, red limestone; *d*, greenstone

The outcrop is on the steep south side of the Mount Muller ridge at a point about 1¼ miles west of Lake Crescent. Development workings made before September, 1925, are distributed through a vertical distance of about 350 feet and consist of short adit levels numbered 1, 2, 3, and 4 in descending order, with raises and stopes and several short diamond-drill holes. From the main adit, No. 3, at an altitude of about 1,800 feet, the ore is transferred to a bin at the foot of the slope, 750 feet below, by a single-span aerial tramway 1,400 feet long. From the bin to Port Angeles the ore is transported on the Lyon & Hill Railway, which was formerly owned by the United States and was known as the Government Spruce Railroad.



POLISHED SURFACE OF ORE FROM THE CRESCENT MINE

Dark specks, bands, veinlets, and irregular areas are hausmannite; light areas are mixed carbonate and silicate (bementite). Enlarged 10 diameters

The first ore produced came from the "discovery" ore body, which lay above adit No. 3 and had been almost entirely worked out by September, 1925. It was a tabular mass from 6 to 14 feet thick, with a greatest length (pitch length) of 180 feet and a greatest width (stope length) of 120 feet. Its volume was about 120,000 cubic feet and it yielded 12,000 tons of ore. The ore body stood nearly vertical, its strike was N. 70°–80° W., and its longest axis pitched steeply westward. The upper part was split by a wedge of country rock and both ore and rock had been slightly displaced by an overthrust fault. (See fig. 1.)

The Crescent ore deposit is inclosed 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. 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. (See analysis on p. 7.) Unlike the porous, cavernous bodies in which manganese oxides produced by the weathering of carbonate lodes occur at Philipsburg, Mont., and elsewhere, the Crescent deposit is hard, dense, and compact. Apparently it has withstood much of the deformation that has sheared and crushed the red limestone wall 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. It occurs in 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 mammillated (pl. 2), 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. Locally small terminated octahedral crystals can be seen with the aid of a good lens. The material has a dark-brown streak and a hardness of 5 to 6.

The occurrence of hausmannite in the Crescent ore was first recognized by Hewett, who observed its resemblance to hausmannite occurring near Bromide, Okla.[24] This determination is confirmed by microscopic examinations by Mr. Ross and the following chemical analysis of material selected by M. N. Short so as to be free from visible impurities:

Partial analysis of selected hausmannite ore from the Crescent mine, Wash.

[Analyst, E. P. Henderson]

Iron oxide, hematite (Fe_2O_3)	0.76
Calcium oxide, lime (CaO)	1.20
Water (H_2O)	1.16
Silica (SiO_2)	3.04
Carbon dioxide (CO_2)	Present.
Manganese oxide (MnO) 86.38, equivalent to metallic manganese (Mn) 66.66 per cent, equivalent to hausmannite (Mn_3O_4)	92.87
	99.11

It is evident that the bulk of the material must be hausmannite, for no other oxide of manganese will so nearly balance the analysis. It is possible that some braunite ($3Mn_2O_3.MnSiO_2$) is present. Probably, however, most of the silica shown by the analysis represents bementite.

Bementite and a manganiferous carbonate compose the smaller part of the Crescent ore. Together they form a dull pinkish-brown material that has a hardness of 4 to 5, fuses to a black glass, and dissolves in hot hydrochloric acid with effervescence. The microscopic character of a specimen from the Crescent mine is described by Mr. Ross as follows:

Specimen C-1 is composed predominantly of hausmannite, but contains 25 per cent of a very fine grained aggregate of brownish manganese carbonate. Associated with the carbonate are areas of very fine-grained bementite. The hausmannite occurs as solid masses and is also disseminated through the areas of carbonate and bementite as rounded or globular masses from 0.01 to 0.1 millimeter in diameter. The carbonate forms irregular areas containing disseminated hausmannite, and in places occurs as sharply bounded veinlets cutting hausmannite. A few veinlets contain a zeolite associated with calcite.

In addition to the minerals described, the ore generally contains small quantities of finely divided iron oxides, chiefly hematite. A little magnetic material occurs in places. A sample analyzed by E. P. Henderson contained 7.72 per cent of iron (Fe), whereas the nonmagnetic material from which the sample was separated contained only 0.75 per cent. Calcite is present, but not abundant in most of the ore. It was the last mineral to form.

The Crescent ore is not only unusually rich in manganese, but comparatively free of constituents that are injurious to steel. In

[24] Hewett, D. F., Manganese deposits near Bromide, Okla.: U. S. Geol. Survey Bull. 725, p. 316, 1921.

fact, it equals the best ore that so far has been available from domestic or foreign sources. Its average quality is shown by the analyses of shiploads aggregating 11,000 tons, reported by the operators as follows:

	Per cent
Manganese (Mn)	50.92 –54.33
Silica (SiO_2)	8.93 – 7.78
Iron (Fe)	1.13 – .74
Phosphorus pentoxide (P_2O_5)	.055– .53

The composition of a sample representing the common hausmannite-carbonate-bementite variety of ore similar to that described microscopically on page 12 is given below:

Partial analysis of manganese ore from the Crescent mine, Washington

[Analyst, J. G. Fairchild]

Manganese (Mn)	57.20
Iron oxide (Fe_2O_3)	.94
Alumina (Al_2O_3)	.00
Silica (SiO_2)	7.65
Magnesia (MgO)	1.10
Lime (CaO)	5.49
Carbon dioxide (CO_2)	4.35

The undetermined constituents include water and phosphorus. The phosphorus, as indicated by the analyses previously quoted, is doubtless very low. The percentages of lime and magnesia shown by the analysis are somewhat in excess of the quantities required to balance the available carbon dioxide. Therefore, as some of the manganese occurs as carbonate, it appears that part of the lime and magnesia occur as silicate, probably contained in the zeolite present.

Below No. 3 adit and about 50 feet to the east another ore body has been discovered by diamond drilling, and still another body is reported by the operators to be exposed in adit No. 4, 135 feet vertically below No. 3. The limits of these bodies had not been determined at the time of visit, but the bodies were shown to be of workable size at least and fully as rich as the discovery body. All three are regarded by the operators as parts of the same mass separated from one another by faulting.

DEPOSITS EAST OF THE CRESCENT

East of the Crescent mine the manganiferous zone has been traced to the end of the Mount Muller ridge at the bend in Lake Crescent, a distance of 7 miles. It is marked by outcrops of red limestone and manganiferous material on the Peggy, Charles G., Charles A., and Mother Lode claims, mentioned in order from west to east, and at points 1½ miles and 4 miles east of the Mother Lode. All are on the same southward-facing slope as the Crescent mine, but at somewhat lower altitudes. Good showings are reported on the Charles G. and Charles A. claims.

Peggy.—An open cut on the Peggy claim, 500 feet east of the Crescent mine, exposes a face of manganese ore 4 feet in maximum width and 15 feet long (pitch length). The country rock is crushed red limestone, from which the ore is separated on one side by a rather smooth plane that strikes N. 60°–70° W. and dips 80°–90° N. and constitutes the hanging wall. The other wall is indefinite, ore and country rock grading together. Several slip planes that branch from the hanging wall (fig. 2) and are marked by streaks of secondary white calcite cut diagonally across the ore body. About 15 feet below the surface the ore is pinched out, but about 60 feet deeper 4 feet of ore was penetrated by the diamond drill. Apparently the ore exposed in the open cut is the lower part of a lenslike body that has been partly cut away by erosion.

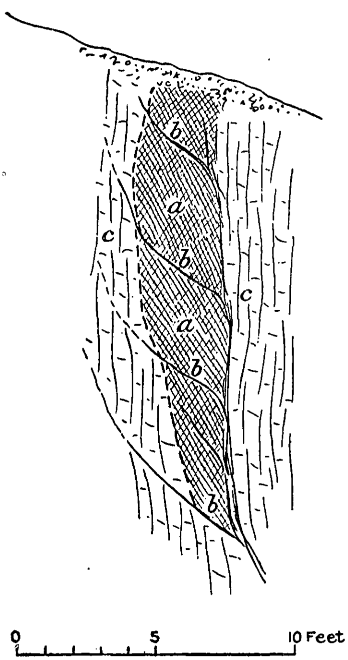


FIGURE 2.—Vertical cross section of ore body on the Peggy claim, near Lake Crescent, Wash. *a*, Ore; *b*, slip plane coated with white calcite; *c*, red limestone

The ore resembles that of the Crescent mine. It consists mainly of hausmannite, which near the top of the body forms a dense bluish-black finely crystalline mass. Just below the surface it is somewhat cavernous, apparently as a result of solution and removal of carbonate. Cavities are lined with small crystals of a short prismatic form, determined by Mr. Ross as probably of the same composition as pyrolusite.

Mother Lode.—The outcrop of a manganiferous ore body on the Mother Lode claim, about 2 miles east of the Crescent mine, is about 200 feet above Crescent Lake. An open cut and a short incline expose a lenslike body of ore that strikes N. 75° W., dips 45° N., and is 2 feet in greatest thickness. The hanging wall is a definite plane that separates the ore from a dark greenish-gray serpentinous-looking rock that shows streaks and veinlets of a white zeolite (laumontite). A description of the microscopic features of the rock is given on page 8. It was originally a basaltic lava. On the other side the ore gives place to a very fine grained red rock consisting essentially of chalcedonic quartz and iron oxides. It is cut by numerous threads and veinlets of a white zeolite and contains fine crystals of a manganese oxide, probably pyrolusite, sparingly distributed on seams.

The ore resembles that of the Crescent mine. It is dense, hard, and fine grained. Microscopic examinations by Mr. Ross show it to consist predominantly of hausmannite, with various contents of carbonate and bementite. Some specimens show seams coated with a resinous-looking reddish-brown substance that is probably neotocite, a noncrystalline variety of manganese silicate having a composition like bementite.

DEPOSITS WEST OF THE CRESCENT

West of the Crescent mine for a distance of 14 miles manganiferous deposits are distributed along a nearly straight line that marks the horizon of red limestone. In order, beginning at the east, are the Kate, Maybee, Littleton, Ed B, and Oberg group, all on the south slope of the Mount Muller ridge. Farther on is a prospect on Bear Creek, and beyond that the State Lease claim, which is on the south side of an unnamed hill between Bear Creek and Beaver Creek. Good showings are reported on the Kate, Maybee, and Littleton. On the Oberg group, which is north of the Snyder ranger station, good-sized bodies of material containing from 25 to 28 per cent of manganese are reported at three places at an altitude of about 900 feet above the valley.

A specimen said to have come from the deposit on Bear Creek, as determined by Mr. Ross, is a compact brown rock consisting mainly of manganese carbonate. Bementite is probably present also, but it is too fine grained to be differentiated.

Ed B.—An exposure of manganiferous material on the Ed B claim, about 4 miles west of the Crescent mine, is 500 feet above the floor of the Lake Crescent-Soleduck River valley. It is easily reached over a trail from the Olympic Highway a mile long. The prevailing country rock is a sheared greenstone, which near the surface shows thin films of manganese oxides on seams. When the rock is broken it tends to separate along these seams, and the fragments therefore may appear to be rich in manganese, whereas they contain but a trifling amount of that metal. Breaking the fragments so as to obtain a fresh fracture reveals their true character. In addition the rock is noticeably lighter (of lower specific gravity) than the local varieties of manganese ore. Microscopic examination of the greenstone by Mr. Ross shows it to be composed of volcanic flows and tuffs in which the feldspars have been partly altered to kaolin and the augite to serpentine and chlorite.

Discontinuous outcrops of red limestone that dips about 30° N. appear along an east-west line and form a continuation of the similar zone exposed at the Crescent mine. Manganiferous outcrops, which appear at intervals for at least a mile, replace the limestone. At one place the limestone-manganese zone is broken by a gap. A few hundred feet to one side, however, is an outcrop that apparently represents the missing portion, its displacement having been caused by faulting.

The lode, which dips about 30° N., or into the mountain, is developed by an open cut and a short winze. At a lower level there is a crosscut tunnel with a raise to the winze, but this working is wholly in country rock. At the open cut the lode consists of two distinct parts, a siliceous layer about 10 feet thick, locally called "cap rock," and a manganiferous layer about 20 feet thick. The siliceous layer is conspicuous among the prevailing dull, dark outcrops because of its bright colors—yellow, red, and brown, with distinct lines and spots of white. In detail it shows a nodular pattern, small rounded areas of dark colors being surrounded by rims of white. The bulk of the material is fine-grained quartz or chalcedony like that from the Star group of claims near Humptulips, described on page 23. The red, yellow, and brown hues are due to finely disseminated iron oxides. The texture of the rock suggests that it has replaced the red limestone.

The manganiferous layer is composed chiefly of a dense, rather hard light to dark brown rock, with bodies of reddish-brown glossy material. The rock is stained black on seams with manganese oxides, which near the surface form thin shells around joint blocks or fragments. These oxides are evidently of recent origin and are due to weathering. They include soft material that stains the hands like wad and a harder glossy-black amorphous-looking oxide. The dense brown material is an indeterminate mixture of manganiferous carbonate and bementite, with more or less hausmannite. The mass observed appeared to be less rich, however, than the Crescent ore.

A specimen of the glossy reddish-brown ore examined by Mr. Ross proved to be neotocite (amorphous silicate of manganese) containing irregular and wisplike areas of bementite. Small amounts of manganiferous carbonate and hausmannite are also present.

State Lease.—The State Lease claims are on the south side of a mountain 2,000 feet high that lies north of the Lake Crescent-Soleduck valley between Bear Creek and Beaver Creek. Manganese ore has been exposed on the hillside by a short trench through the surface mantle at a ponit about 400 feet above the valley and a mile east of the road extending from the Olympic Highway to Clallam. The ore body occurs in red limestone, and as incompletely exposed strikes N. 75° W. and dips about 40° N. It consists mostly of fine-grained aggregates of hausmannite in a yellowish to pinkish-brown groundmass of manganiferous carbonate and bementite. Except that this material has been considerably sheared and crushed, and cut by small seams of calcite, it closely resembles the ore from the Crescent mine. There is present also glossy brown to black material like the neotocite-bementite rock of the Ed B claim. Adjoining the ore is a body, whose thickness is not shown, of siliceous material consisting of chalcedonic quartz with iron and manganese oxides.

HUMPTULIPS AREA

Star.—Claims known as the Star No. 3, Star No. 4, and Star No. 5 are part of a considerable area covered by mineral locations on the spur between Cook Creek and Skunk Creek in sec. 30, T. 22 N., R. 9 W. They are reached by a short trail that leads east from the Olympic Highway at a point 10 miles north of Humptulips. The railroad of the Polson Logging Co. passes about 1¼ miles west of the claims.

An open cut on the Star No. 5 shows a manganiferous lode about 15 feet wide that strikes northeast and lies between red limestone and greenstone. Most of the exposure consists of carbonate-bementite rock, which near the surface is slightly weathered along joints. As a result the joint blocks or fragments into which the lode is separated are surrounded by shells an inch or less thick of soft mixed oxides that are difficult to separate and identify. Pyrolusite and wad probably are present, and locally there is considerable iron oxide. The unweathered material is hard, dense, and extremely fine grained. Part of it resembles ore from the Crescent mine, though hausmannite was not positively identified in it. Most of it is like the variety of bementite rock from the Skokomish region that shows translucent waxy reddish-brown patches and veinlets of neotocite,[25] an amorphous silicate of manganese similar to the bementite in composition. In places there is an indistinct mottling, which suggests that the ore has replaced red limestone. A face 6 by 6 feet in area of similar material is exposed by a cut about 150 feet to the northeast. Possibly this is an extension of the same lode. The siliceous material or "cap rock" consists of a porous groundmass of fine-grained quartz stained with brown and red iron oxides and cut by seams of black manganese oxides.

A short distance east of the exposure described several cuts on the Star No. 3 and Star No. 4 claims show the outcrop of a lode that extends at least half a mile N. 60°–70° E. At the southwest, on the Star No. 4 claim, a cut made by J. L. Bockover in 1917 shows several feet of "cap rock." Representative specimens of this material are composed of chalcedonic quartz stained brown or red with iron oxides and locally cut by veinlets of small hausmannite crystals.

[25] Pardee, J. T., Deposits of manganese ore in Montana, Utah, Oregon, and Washington: U. S. Geol. Survey Bull. 725, p. 234, 1921.

About 300 feet to the northeast is a more recent cut that shows a face measuring 10 by 15 feet of mixed bementite rock and "cap rock" like that on the Star No. 5 described above.

About 400 feet farther northeast, on the Star No. 3 claim, is an outcrop of "cap rock" about 6 feet wide, and a short distance beyond this a small exposure of "cap rock" and ore. A white variety of the "cap rock" at this place is somewhat porous and sparingly peppered with small grains of black manganese oxide, apparently hausmannite. A microscopic examination by Mr. Ross shows it to be composed of fine-grained quartz with a structure resembling a rhyolitic lava flow. This structure is apparently inherited from some rock which has been completely replaced. The silicified material is cut by numerous veinlets of later chalcedonic quartz and by still later veinlets of calcite. Another variety of "cap rock" is a yellowish-brown jaspery-appearing material streaked with black. The microscope shows it to be composed of chalcedonic quartz and oxides of iron, with probably a small quantity of manganese oxides. The mass is composed of small red spherical or oolitic bodies in a darker opaque groundmass. Still another variety is a deep-red siliceous hematite.

Manganiferous material exposed to a small extent in the outcrops on the Star No. 3 claim consists of bementite-neotocite-carbonate rock like that on the Star No. 5 claim.

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