

# PRELIMINARY REPORT ON THE CHROMITE OF KENAI PENINSULA.

By A. C. GILL.

## INTRODUCTION.

The chromite deposits of Kenai Peninsula are situated at two localities near the southwestern extremity of the peninsula. (See Pl. I.) One of these deposits forms the rocky peninsula called Claim Point, at the entrance to Port Chatham, where the town-site named Chrome has recently been located, and extends for a short distance onto the adjacent mainland of the peninsula. It is thus practically at tidewater. The other is 16 miles to the northeast, at Red Mountain. Chrome ore has been produced only at Claim Point. Nearly a thousand tons from this locality in 1917 and approximately the same amount in the season of 1918 seem from available records to constitute Alaska's entire contribution to the chrome industry. Previous publications on these deposits include reports by Grant,<sup>1</sup> who visited both areas in 1909, noted the character of the igneous rock, and mentioned two of the chromite deposits; by W. P. Lass,<sup>2</sup> of the firm Whitney & Lass, owning and operating the Claim Point property, who has published a statement of the quantity, quality, and conditions of shipment of his firm's product for the season of 1917; and by J. B. Mertie, jr.,<sup>3</sup> who in the summer of 1917 gathered data concerning the chromite at both localities. The following pages include the more important economic conclusions derived from a detailed study of these chrome-bearing areas made during the season of 1918. A more extended account of these investigations is in preparation.<sup>4</sup>

## GEOLOGY.

The country rock in which the chromite occurs consists of masses of dunite, which are surrounded by beds of more or less metamorphosed clastic rocks, chiefly slates and graywackes. The metamorphic

<sup>1</sup> Martin, G. C., Johnson, B. L., and Grant, U. S., *Geology and mineral resources of Kenai Peninsula, Alaska*: U. S. Geol. Survey Bull. 587, p. 237, 1915.

<sup>2</sup> Lass, W. P., *Chrome deposits of Alaska*: Min. and Sci. Press, Nov. 3, p. 653, 1917.

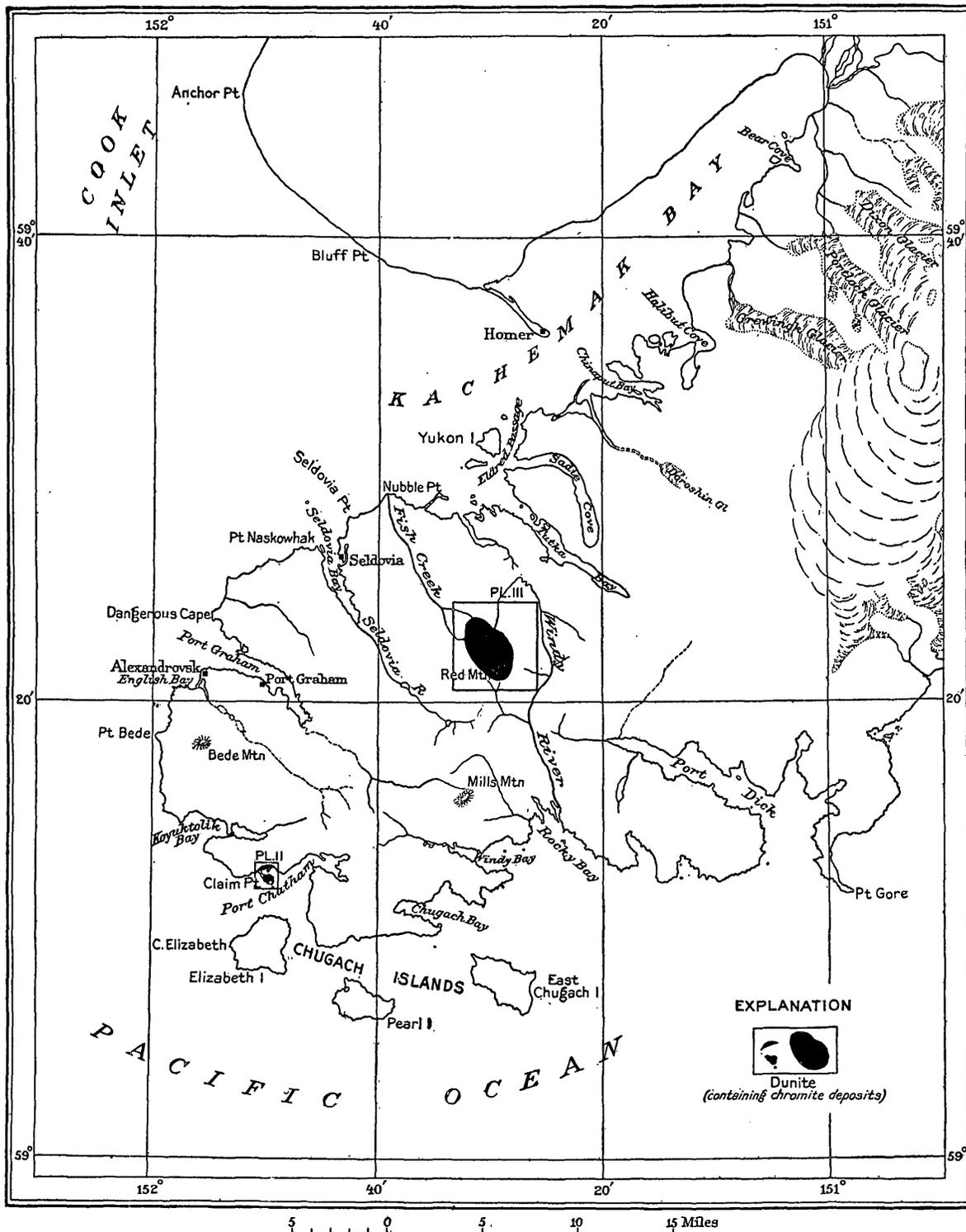
<sup>3</sup> Mertie, J. B., jr., *Chromite deposits in Alaska*: U. S. Geol. Survey Bull. 692, pp. 265-267, 1919.

<sup>4</sup> Gill, A. C., *Chromite of Kenai Peninsula, Alaska*: U. S. Geol. Survey Bull. — (in preparation).

rocks include black slates, cherts with quartz veinlets, graywacke of sandy or arkosic composition, and graywacke with lenticular carbonate layers, containing included shale fragments or presenting a marked "greenstone" aspect. The general characteristics of these rocks are described by Martin, Johnson, and Grant in Bulletin 587. The alterations of these rocks near the dunite contacts are in general slight, certainly much less than appears in rocks lithologically similar at their contacts with the diorite near Point Bede and south of the entrance to Koyuktolik Bay.

The mass of dunite at Claim Point is so nearly surrounded by water that its exact boundaries and dimensions can not be given. It doubtless occupies the whole of the Claim Point hill, for it is exposed around the entire base of the hill, either along the shore or in a low bluff rising from the grass flats to the northwest. It probably also underlies these grassy flats, a portion of which forms the narrow neck connecting Claim Point with the mainland of Kenai Peninsula, and it is exposed along the base of the mountains on this mainland at many points, the most widely separated of which are three-quarters of a mile apart. The dunite does not show along the base of the main ridge west of the Claim Point neck, though the metamorphosed condition of the rock just west of the junction of this neck with the mainland may indicate its proximity. The extreme observed distance between exposures in an east-west direction is almost exactly a mile and in a north-south direction seven-eighths of a mile as shown on the accompanying map (Pl. II). The dimensions of the dunite mass are of course greater than this.

The dunite area at Red Mountain is somewhat elliptical in shape. Its length from northwest to southeast is about 4 miles, and its width only 2 miles. Its area is approximately 7 square miles. (See Pl. III.) The main summit of Red Mountain is near its southeast end, forming part of a dunite ridge which is shaped like a somewhat distorted horseshoe with its opening toward the north, through the valley of Windy River. The boundaries of the igneous mass may be approximately followed with the utmost readiness, uncertainty arising only at the outlets of cirques where former glaciers have deposited their pluckings from the highly jointed dunite. Except by the roundabout course of Windy River, passage from the inner basin to the outer slopes of the horseshoe ridge can not be found at altitudes less than 2,150 to 2,700 feet. Transportation to tidewater (see p. 126) thus becomes a very different problem for the different parts of the area, though the distance necessary to be traversed may be nearly the same.



MAP OF WESTERN PART OF KENAI PENINSULA SHOWING CHROMITE DEPOSITS AND POSITION OF DETAILED MAPS.

**ORE DEPOSITS.****GENERAL FEATURES.**

The outstanding peculiarity of the Kenai Peninsula chromite bodies is their continuity for considerable distances in the shape of bands or layers, as contrasted with the "pockety" character exhibited by such ores at most localities. This extension in the layers is not so pronounced at Port Chatham as in the Red Mountain region, though even here it is unusually well developed. Two typical cases may be cited in order to give definiteness to this statement.

At the Reef mine, at Claim Point, the length of the deposit is about 135 feet. At the east end its thickness is about 3 feet; a section measured near the middle showed 47 feet 4 inches; and another toward the west end 23 feet 2 inches. The thickness near the middle is thought to be approximately doubled by faulting. All these measurements include more or less rocky material, occurring in parallel banding with the chromite.

The most extended ore body observed in the Red Mountain district is on the Star Chrome No. 4 claim. Its width ranges from 6 to 11 feet for a distance of more than 600 feet, and it is continued for at least 500 feet more to the north in the form of separate stringers some of which are a foot or so in thickness. Smaller stringers are numerous at many places where there is no workable ore. Some were noted with a thickness of a quarter of an inch and a length of 2 feet; some 2 inches thick and 8 or 10 feet long. All show the same general layer-like shape.

The chrome ores of both districts are highly variant in appearance. Two pronounced types are chosen for purposes of description, though intermediate forms are quite as abundant as these. One is a granular black massive rock, with lustrous surfaces where freshly broken, becoming dull brown through attrition of the fragments. The other is a banded variety, in which light and dark layers in parallel or nearly parallel position present a striking color contrast. The layers in the banded ores range from less than a twentieth of an inch to several inches in thickness, though on closer inspection the wider bands usually appear to possess a certain degree of subsidiary banding with more indistinct boundaries between the light and dark colored portions. The dark constituent is chromite, and the light-colored part is usually olivine, which is doubtless very low in its iron percentage, or much more rarely a light-green monoclinic pyroxene, which may prove on further study to be chromiferous and may be similar in origin to the pyroxenite bands in the dunite.

The mineral composition of the chrome ores is very simple. They are mixtures of chromite and olivine in all proportions, with accessory pyroxene at a few localities. Possibly some of the peripheral masses may be found to contain serpentine or other weathering products instead of olivine.

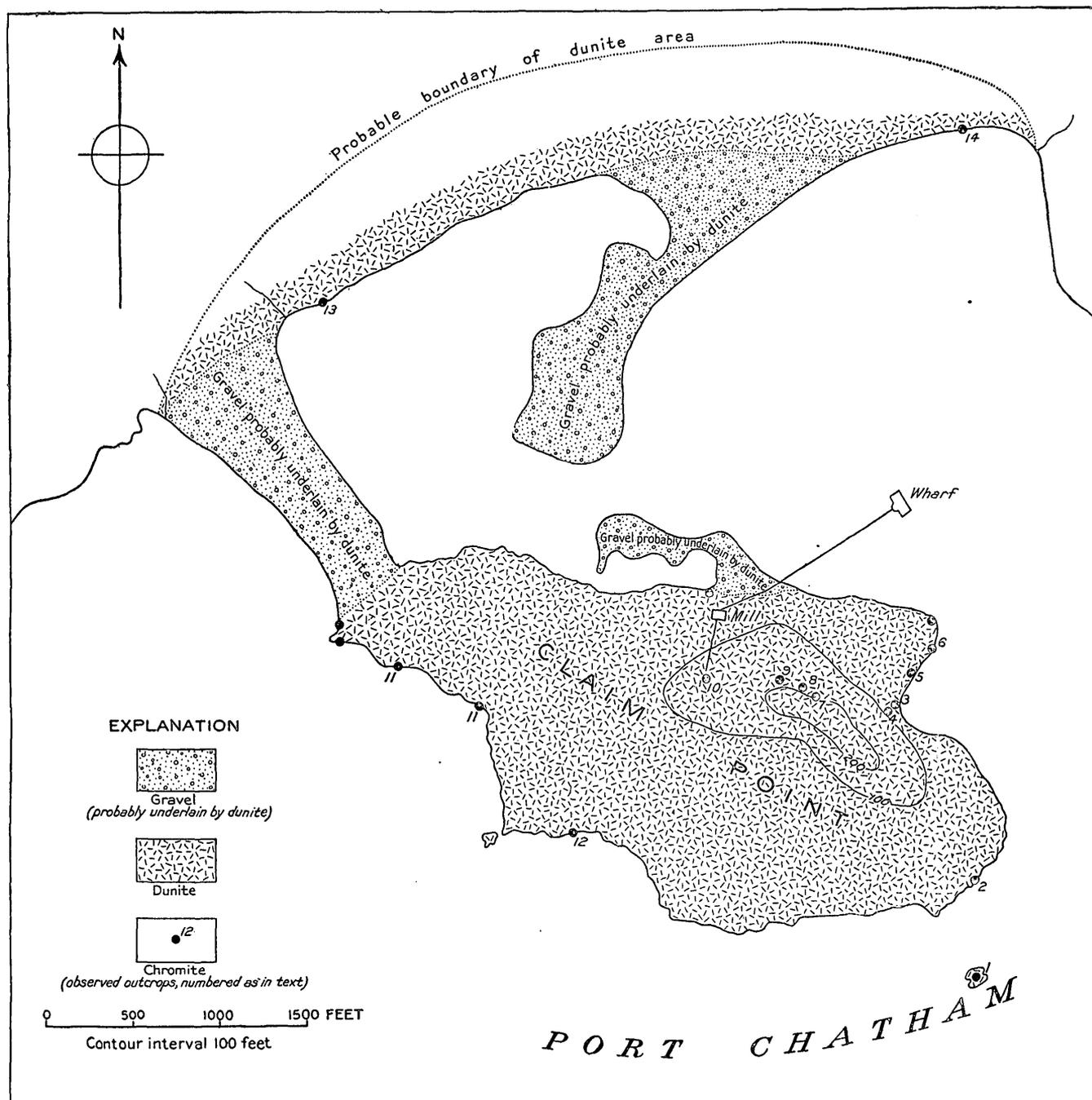
#### PORT CHATHAM.

##### DEPOSITS.

Fourteen separate deposits which under normal market conditions might yield more or less chromite were observed. As will be shown in the later discussion, this number is by no means exact. For example, in the high sea wall at the head of the cove near the northwest end of Claim Point hill no less than eight separate patches of banded ore are visible. Three of these show plainly that they are faulted portions of what was originally a continued set of stringers. On the whole, it seems probable that the eight or more separate masses are dislocated portions of two stringer systems, about 30 feet apart and in parallel position, and hence in enumerating the fourteen deposits these were counted as two. The deposits on the hill to the west are believed to be continuations of the same two bands, yet they are counted as three more because definite evidence of their continuity is lacking, and in any event the connecting portions may very likely not be of workable quality.

The masses of chromite occur chiefly in bands or layers or composite series of layers ranging from a fraction of an inch to 40 feet or more in thickness and from 3 or 4 inches to more than 200 feet in length. These chromiferous bands are in some places composed of massive granular chromite, in others of more or less disseminated grains and octahedral crystals distributed in maximum abundance along parallel roughly plane surfaces. The characteristics of these ore bodies may perhaps best be presented by describing in some detail each that seems capable of furnishing marketable ore, even though the quantity may not be large. The positions of such ore bodies are indicated on Plate II.

1. On a small island which lies southeast of Claim Point hill and which at low water is connected with the mainland by a narrow rocky neck is the Reef mine, operating on the ore body from which most of the chromite thus far shipped from Alaska has been taken. The strike of this ore mass is S. 76° W. and its dip nearly vertical, though the component ore bands show much local variation in dip and strike. Its length is about 135 feet and its width varies from 3 to perhaps 35 feet. A section across the main heading at high-tide level was measured on July 9, 1918, as follows:



MAP SHOWING CHROMITE DEPOSITS AT CLAIM POINT, PORT CHATHAM.

*Section at main heading, Reef mine.*

	Ft.	in.
Dark ore, 40 per cent.....	6	0
Rock.....	1	2
Mostly black, with 5 or 6 inches half silicate.....	2	3
Mostly waste, containing some chromiferous bands.....	1	7
Black ore with 2-inch diagonal "dike".....	2	0
Massive black ore.....	2	2
Waste.....	2	6
Half and half.....	1	0
Waste.....	1	0
Half chromite in wedge-shaped bands.....	5	5
Massive ore, good to medium quality.....	11	1
Mostly waste.....	6	3
Shipping ore.....	1	0
Waste.....	2	6
Good ore, 40 per cent.....	1	5
Scattered stringers, no sharply defined wall.	47	4

Faulting has doubtless increased the apparent thickness along this line, probably by at least 10 feet, and for a conservative estimate of quantity it may be considered that the following section shows its normal magnitude:

*Section 50 feet southwest of main heading, Reef mine.*

	Ft.	in.
35 per cent ore.....	2	9
Waste.....	6	6
Shipping ore 40 per cent or better.....	7	11
Disseminated ore, 15 to 20 per cent.....	6	0
	23	2

The highest point on the good ore between these two measured sections is about 18 feet above mean low tide. There is some poor ore 5 to 10 feet higher still to the southeast of the main lode. The depth below water level, according to the assumption that it is half of the horizontal length, would be 65 to 70 feet. The impression of the mine operators that this mass of ore is becoming larger at greater depths seems to be corroborated by Mertie's measurement of 20 feet for the maximum thickness in 1917 as compared with 23 to 34 feet in 1918, and by a divergence of perhaps 5° or 10° in the walls. As will be shown in the tonnage estimate, the part of the ore below tide at the Reef mine is doubtless greater than that above, even without assumption of increasing thickness at the lower levels.

The content of chromic oxide in this ore reached 46 to 49 per cent in the product of 1917. In the season of 1918 the operators found it advantageous to approximate a 40 per cent ore, on account of market conditions, their contracts not providing for a higher unit value for

richer ores. It is thus no indication of a deterioration in the quality of the ore that the later shipments have not maintained the percentage of the first season. During both years a certain amount of low-grade ore has been broken and not used which will be available for concentration when the mill is in operation.

2. In the low sea wall just east of the miners' quarters, which are near the shore about north of the Reef mine, is a small exposure of chromite 15 to 20 inches thick and about 20 feet long. The ore is in part of shipping grade and has been worked to a slight extent, chiefly for exploration. The strike is N. 70° E. and the dip nearly vertical. A smaller mass to the east may well be, as suggested by Mertie, a faulted part of the same deposit, but it seems not to be of workable magnitude.

3 and 4. In the high sea cliff at the head of the bight northeast of Claim Point hill is an inaccessible exposure of what seem to be two much disrupted stringer systems of banded chromite probably originally parallel and some 30 feet apart. Their thickness is estimated at 3 or 4 feet, and their vertical extent at 50 or 60 feet. The ore appears to be mostly of low grade, though some of the fallen fragments are judged to contain at least 30 per cent of chromite oxide. At the base of the cliffs at a distance of less than 50 yards in both directions from the main exposure are many chromite stringers of very low grade. Their original continuity with the higher masses is extremely hypothetical, yet the shattered condition of the country rock is such as to suggest faulting, and with the probability that the vertical component of the throw is here, as at the Reef mine, much greater than the horizontal component, the change in character of the deposit is not greater than might be expected.

5. About 75 yards north and east from the high wall just mentioned is a set of very irregular lenses and stringers of chromite exposed for a height of 25 feet just above the beach. At the bottom are small stringers, but in the middle there is some shipping ore, though even in this part concentrating ore is much more abundant. The maximum thickness is nearly 20 feet, perhaps through repetition of a smaller body by slipping and faulting. A little of this ore has been shipped

The associated rock is serpentine of a brownish color, which appears to be especially thoroughly weathered on account of its proximity to the fault zone and consequent free access of water.

6. At 50 yards east of No. 5, below high-tide level, is a sharply bounded lens of massive chromite exposed at low tide for a length of about 60 feet and a maximum width of 26 inches. For only 24 feet, however, is its width above 7 inches. Its strike is N. 86° W., which would carry it very near to the last-mentioned deposit. Under

the action of wave-driven pebbles and boulders it has proved less resistant than the dunite walls, so that it is exposed in the bottom of a small gully. This gully can be seen to continue for some distance under water, indicating a greater extent than is actually exposed. Shifting sand and gravel fill this eroded notch at times, completely covering the ore, as was observed on a second visit to the locality. This chromite was found to have a specific gravity of 4.37 to 4.44, and a sample analyzed by Chase Palmer in the chemical laboratory of the United States Geological Survey gave 46.84 per cent of chromite oxide. A white mineral in the cracks of this ore appears to be aragonite.

7. On the upper slope of the hill about 150 yards N. 76° W. from deposits Nos. 3 and 4 is a pit made for the purpose of developing one of the banded stringer systems of low-grade chromite. This pit is about 30 feet long, showing an ore-bearing width of 118 inches at the east end and 128 inches at the west (upper) end. The strike of the bands is N. 69° E. and their dip about 70° SE. The best of this ore for a thickness of 6 feet is estimated to carry 25 to 30 per cent of chromic oxide, and the remaining 4 feet or more averages perhaps half as much. The silicate constituent is partly monoclinic pyroxene of a greenish color, in places occurring as  $\frac{1}{3}$ -inch dikes cutting diagonally across the ore bands, and partly a light-colored olivine which weathers to a rusty yellow color.

About 100 feet S. 76° E. from the pit in a direct line toward the exposures in the sea wall is a natural exposure of many chromite stringers, which may be a continuation of the same deposit, faulted and displaced toward the south from that portion uncovered in the excavation. In order to express the legitimate doubt as to the continuity of these exposures the length of the ore body may be reduced one-half, namely, to 65 feet, in estimating its magnitude.

8. In another test pit 40 feet northwest of No. 7 a similar ore body is exposed for a length of 50 feet but is less sharply defined in its banding. It maintains the same strike and has a dip of about 80° SE. Its cross section shows 80 inches of ore, three samples from which have a specific gravity of 3.62 to 3.7, averaging 3.66, while on each side of this is poorer ore for a thickness of 2 to 3 feet. From the specific gravity of this ore, on the assumption that 3.3 is the density of the silicate constituent and 4.4 that of the chromite, somewhat more than 39 per cent of the better portion of the deposit is chromite, carrying approximately 20 per cent of chromic oxide. The inferior ore nearer the contacts is judged to be about half as rich.

Another development pit about 90 feet to the southwest is believed to be on the same ore body, though slightly offset to the right. The

strike of the bands is still N. 69° E., and the dip is nearly vertical. The exposed cross section measures 25 feet, and the ore is mostly of similar quality to that just noted, though in the southeasterly part of the pit the ore bands seem to be more sharply segregated from the rock, showing 12 or more bands of black, high-grade ore ranging from 1 inch to 2½ inches in thickness. The thicker bands may furnish a small amount of shipping ore. The total length of the ore mass is probably more than is indicated by the two excavations—that is, 140 feet, for a considerable number of rich chromite stringers ranging from half an inch to 4 inches in thickness occur nearly on the strike at a distance of 125 feet to the northeast. The width of the ore bands for the distance exposed by the two pits may be taken as 18 feet, for it is 11 feet in one and 25 feet in the other.

9. On the hillside 60 feet about N. 20° W. from the westerly opening on No. 8 is a rich chromite lens 4 inches wide and 4 or 5 feet long. It is accompanied by many smaller chromite stringers on both sides. It is doubtful if this is a portion of a workable deposit. It is interesting on account of a small fault that displaces the ore about 6 inches, indicating the presence of fractures in this region. There seem to be scattered stringers over a considerable width here, as in an opening 60 feet farther down the hillside in a direction N. 20° W., which was made with the intention of crosscutting by a tunnel to ore body No. 8, are exposed a few small ore bands. The strike of all these bands is about N. 70° E. and the dip nearly vertical.

10. What seems to be the largest chromite deposit at Claim Point—if, indeed, it is not part of an originally continuous mass 1,200 feet or more long connecting bodies Nos. 3 and 4 by way of Nos. 7 and 8 with this outcrop—is about 500 feet N. 68° W. from the west end of No. 8 and a little lower on the hill slope. It is thus offset about 250 feet to the right from the line of strike of the higher ore. Nothing more definite as to their original continuity can at present be offered than the observation that many small faults have been observed in the region, all with displacement in such sense as to indicate continuity if the proper amount of throw were present either in small steps or in one or more larger breaks.

This ore body is the central point in the plans for immediate future development. From it the tramway starts, and ore bins, mill, and wharf have been placed with reference chiefly to the handling of its output.

The ore body was only very slightly exposed by natural outcrop, and even when it was visited for the purposes of this report, development work had not progressed sufficiently to afford a clear view of its magnitude. A partly uncovered cross section at the end of the tramway up an irregular slope gave the following figures:

*Section at end of tramway on deposit No. 10.*

	Ft.	in.
15 per cent Cr <sub>2</sub> O <sub>3</sub> (?)-----	5	5
35 per cent Cr <sub>2</sub> O <sub>3</sub> -----	4	7
5 per cent Cr <sub>2</sub> O <sub>3</sub> (too rocky to work?)-----	2	2
50 per cent Cr <sub>2</sub> O <sub>3</sub> -----		8
35 per cent Cr <sub>2</sub> O <sub>3</sub> -----	10	0
Covered by soil and vegetation-----	18	0
50 per cent Cr <sub>2</sub> O <sub>3</sub> -----	1	6
	<hr/>	
	47	9

In this cross section the ore estimated at 25 per cent chromic oxide is by no means homogeneous but is made up of streaks of poorer and richer material. Two chips from a specimen collected to represent its average quality gave specific gravities of 3.79 and 4.03, or an average of 3.91. On the assumptions that the specific gravity of the silicate constituent is 3.28, as found for the purest of the silicate rock (as a matter of fact this rock contained a little chromite), and that the chromite has a specific gravity of 4.4, the ore tested would contain 63 per cent of chromite. If either the silicate mineral or the chromite actually has a lower specific gravity than is above assigned, the percentage of chromite must be greater. Both these conditions are very probable, because, (1) as above noted, some chromite was present in the silicate material on which the determination of specific gravity was made, and furthermore the silicate portion of the ore appears somewhat dull as if partly hydrated, and (2) the blackest pieces of the chromite show a specific gravity of only 4.17, though not more than 10 per cent of the fragments used appeared to be silicate.

The position of the bands is more irregular than in most of the ore masses, the strike ranging from N. 34° E. to N. 59° E., though mostly about N. 54° E. The dip is nearly vertical, in some places southwesterly.

In order to obtain for the purposes of this report some idea of the length of the deposit a workman, furnished by Whitney & Lass, made several small excavations along a cross section about 100 feet to the southwest. Four of these reached bedrock, and in all of them ore similar to that at the main exposure was found. The extreme width of the ore indicated by these pits was about 45 feet, but neither wall was uncovered.

Along a cross section some 75 feet farther to the southwest he dug two pits 8 feet apart to bedrock. Both showed ore judged to be like other ore, of which the field estimate was 15 per cent of chromic oxide and the laboratory determination 28.62 per cent. Owing to the soil covering and the irregularity of the bedding it is impossible to decide whether this poorer ore indicates decreasing chromite content

along the strike or is simply, as is so frequently observed elsewhere, a leaner band interbedded with better ore. To the northeast of the main exposure the chromite was found at a distance of 25 feet, though only slightly exposed. The total length is thus at least 200 feet, probably more, and the width may be placed tentatively at 30 feet.

11. Along the rocky shore where the low-lying west end of Claim Point hill is exposed to the open ocean there are many stringers of chromite in more or less detached exposures for an extreme distance of some 500 feet. At the westernmost exposure their strike is S. 86° E., which would carry them, if they continue on this course under the covering of vegetation, very near to deposit No. 10, 1,500 feet to the east. Their dip is 60° or 70° S. They are mostly below high-tide level. The ore is variable in quality, including several lenticular bands of high-grade chromite 2 to 6 inches thick and 4 to 8 feet long. At three or four points a thickness of 4 feet of fair concentrating ore is reached. The variation in quality along the strike is so great that no valuable estimate of the amount of ore rich enough for concentration can be made, as no length can be assigned to the workable portions. It can only be stated that doubtless a considerable amount could be procured above low tide, and very likely a larger quantity at greater depth.

12. About 600 feet southeast of the east end of the last-mentioned series of deposits, also along the shore, is a set of chromite bands striking N. 52° E. and dipping almost vertically. The chromiferous zone is about 30 feet wide, with indefinite boundaries. Single layers of clean chromite reach about an inch in thickness. Some of these can be traced continuously for 10 to 15 feet. Of this material 28 inches, in five or six bands two of which were about 8 inches thick, was estimated to be half chromite. Perhaps 10 feet or even more might prove to be of concentrating grade. At 50 feet to the east is another exposure of similar ore about half as wide. It is thought to be a portion of the same bands, offset, as usual, to the right as the outcrop is followed.

13. On the beach at the base of the cliffs northeast of Claim Point hill is a considerable amount of chromiferous sand which has been much concentrated by wave action, though still containing a large percentage of what appears to be olivine. Whether this is rich enough for direct shipment or should be further concentrated had not been determined at last reports, though it seems highly probable that with a mill in operation removal of more of the waste would be found desirable. The sand has evidently been derived from the friable rock by wave action. Its quantity is small, compared with the deposits which occur in place, yet it and other occurrences of similar character that may be hereafter found are worthy of consideration.

14. A deposit of chromite of no considerable economic importance is situated in the brecciated zone near the dunite boundary about half a mile north of Claim Point hill, across the small bay from the wharf. It occurs as a chromite breccia in several separated masses, the largest some 6 feet in diameter, composed chiefly of angular fragments that appear to have been broken from larger deposits, perhaps by magmatic pulsation. Some of the interstitial spaces between the brecciated fragments are empty; others are filled with original silicate material or with what looks like a talcose alteration product. It is possible that the open spaces have been caused by removal of the carbonated or otherwise altered silicate constituent.

So far as their evidence goes, these deposits may indicate that large continuous bodies of chromite are not to be expected in the brecciated outer zone of the dunite, the originally large bodies having been completely broken into detached masses.

#### QUALITY OF ORE.

No thorough study has been made of the nature of the chromite constituent of the Port Chatham ores nor of the mineralogic nature of their impurities. For the season of 1917 Lass<sup>1</sup> reports 46 to 49 per cent of chromic oxide in the output of the Reef mine. The product for 1918 was selected to approximate 40 per cent, for the contract conditions made such selection preferable to marketing only the richest ore, as had been previously done. The percentage of chromic oxide in the bulk ore has hitherto been the main factor considered in determining quality. For purposes of checking field estimates and judging the significance of specific gravity in determining the quality of these ores, three determinations were made on the Port Chatham material by Chase Palmer in the chemical laboratory of the United States Geological Survey, with the following results:

	Per cent of Cr <sub>2</sub> O <sub>3</sub> .
Deposit No. 6, specific gravity 4.4-----	46.84
(Reef mine) deposit No. 1, specific gravity 3.79-----	34.67
Deposit No. 10, specific gravity 3.58-----	28.62

#### TONNAGE.

The amount of ore present is computed on the assumption employed by J. B. Mertie, jr., in his preliminary study of the region, that extension in depth was originally substantially equal to horizontal length, and that the agencies of erosion which have exposed the deposits have, in that process, removed on an average half of each ore body. With cumulative evidence that the horizontal extent is greater than is shown by the exposures, either on account of faulting or covering by débris or both, it is difficult to make conservative estimates as to depth. Assumptions as to continuity have been dis-

<sup>1</sup> Lass, W. P., Min. and Sci. Press, No. 3, 1917, p. 653.

cussed in the descriptions of the individual deposits. Deposits that are calculated as containing less than 100 tons of ore are not included in the summation, for the probable error in the larger numbers is much greater than this amount. An attempt is made to discriminate roughly between shipping ore, placed at 40 per cent or more of chromic oxide, and concentrating ore, which is arbitrarily defined to include that which runs 10 to 40 per cent. Field estimates of quality, in which the judgment of those who have worked with these ores was kindly offered and freely used, are made the basis of calculation. The estimated percentages of chromite have been found to check reasonably well with the specific-gravity determinations, though it should perhaps be stated that chemical analyses, of which six were made, give an unexpectedly high content in chromic oxide for the lean ores and a lower amount than was foreseen for the richer specimens. These facts can be explained only by further investigation.

In the following table the ore bodies are designated by the numbers employed in the detailed descriptions:

*Estimated quantity of chromite ore at Port Chatham as calculated from the observed dimensions, in tons.*

No.	Shipping ore.		Concentrating ore.		Chromite in concentrating ore.	
	Above tide level.	Below tide level.	Above tide level.	Below tide level.	Above tide level.	Below tide level.
1.....	1,300	10,000	550	4,800	300	2,500
3,4.....			1,000		350	
5.....			300		100	
7.....			2,300		750	
8.....			20,000		6,000	
10.....	10,000		60,000		24,000	
11.....				6,000?		1,200
12.....				1,000?		200
	11,300	10,000	84,150	11,800	31,500	3,900

Disregarding the concentrating ore in its crude condition and assuming a recovery of two-thirds in the concentrating process, we find that the final estimates of exportable ore would be, above tide level, 32,300 tons; below tide level, 12,600 tons.

#### MINING AND SHIPMENT.

At Port Chatham the mining operations have been conducted by open-cut workings, chiefly at the Reef mine. Great inconvenience has been experienced from the tides, as a large part of the output has been taken between high and low water. Any considerable additional production from this deposit will necessitate an entire change of method, as the portion of ore above low water has been

largely removed. It is therefore probable that the next deposit to be exploited will be that numbered 10 in the list of descriptions. At this deposit relatively light stripping will uncover a large body of ore on the hillside in favorable position for removal. Open-cut methods will reach a large tonnage and may be found practicable to a considerable depth, for the width of the deposit is 30 to 50 feet, and the walls are of solid rock.

Operations on deposits numbered 2, 5, 7, 8, 9, 10, 13, and 14 have been as yet of rather exploratory character, though a little ore from several of these deposits has been shipped.

Facilities for shipping the Port Chatham ore have been much improved during the season of 1918. A new wharf has been constructed in the bay north of Claim Point hill, and it is reported that with the cooperation of the United States Coast and Geodetic Survey a wire drag of the harbor was carried out.

### RED MOUNTAIN.

#### DEPOSITS.

In the Red Mountain area not less than 23 deposits capable of furnishing chrome ore when transportation conditions are favorable were observed in place. In addition to these, at least 10 occurrences of good ore in loose blocks were noted. Some of these float indications bespeak heavy deposits; others may have been derived from bodies too small or too much crushed to be workable. The abundant and rich-looking chromite fragments east of the main head of Windy River have very likely been in large measure brought by glaciers from the great mass to the southeast, on which the Star Chrome No. 4 claim is located. As a rule, however, the loose material is judged either to be without much doubt derived from ore bodies not seen in place, or, if from any of the ore bodies that were seen, to be so located as to indicate an immensely greater extension of those bodies than was assumed in the quantity estimates.

The number of mining claims located in this district is, as nearly as could be ascertained, 49, of which 14 are held by Whitney & Lass, 19 by F. P. Skeen, 10 by Babcock & Martin, 3 by Cramer & Martin, and 3 by R. V. Anderson. According to common report, all other claims made at earlier dates have been abandoned.

The ore bodies observed in place at Red Mountain occur as a rule in the firm jointed dunite and not in the crushed and hydrated outer zone. The single exception is deposit No. 22, which is in the peripheral material. Hence the location of the larger ore masses is chiefly on the inner or outer walls of the horseshoe ridge. The fact that most of them were found at somewhat high altitudes seems due

rather to the débris covering of the lower slopes than to a less abundant supply of chromite in the lower rocks. If any portion of the area is really devoid of workable chromite it would seem to be the southeast slope and cliffs of the spur between the upper drainage basins of Fish Creek and the northerly fork of Seldovia River.

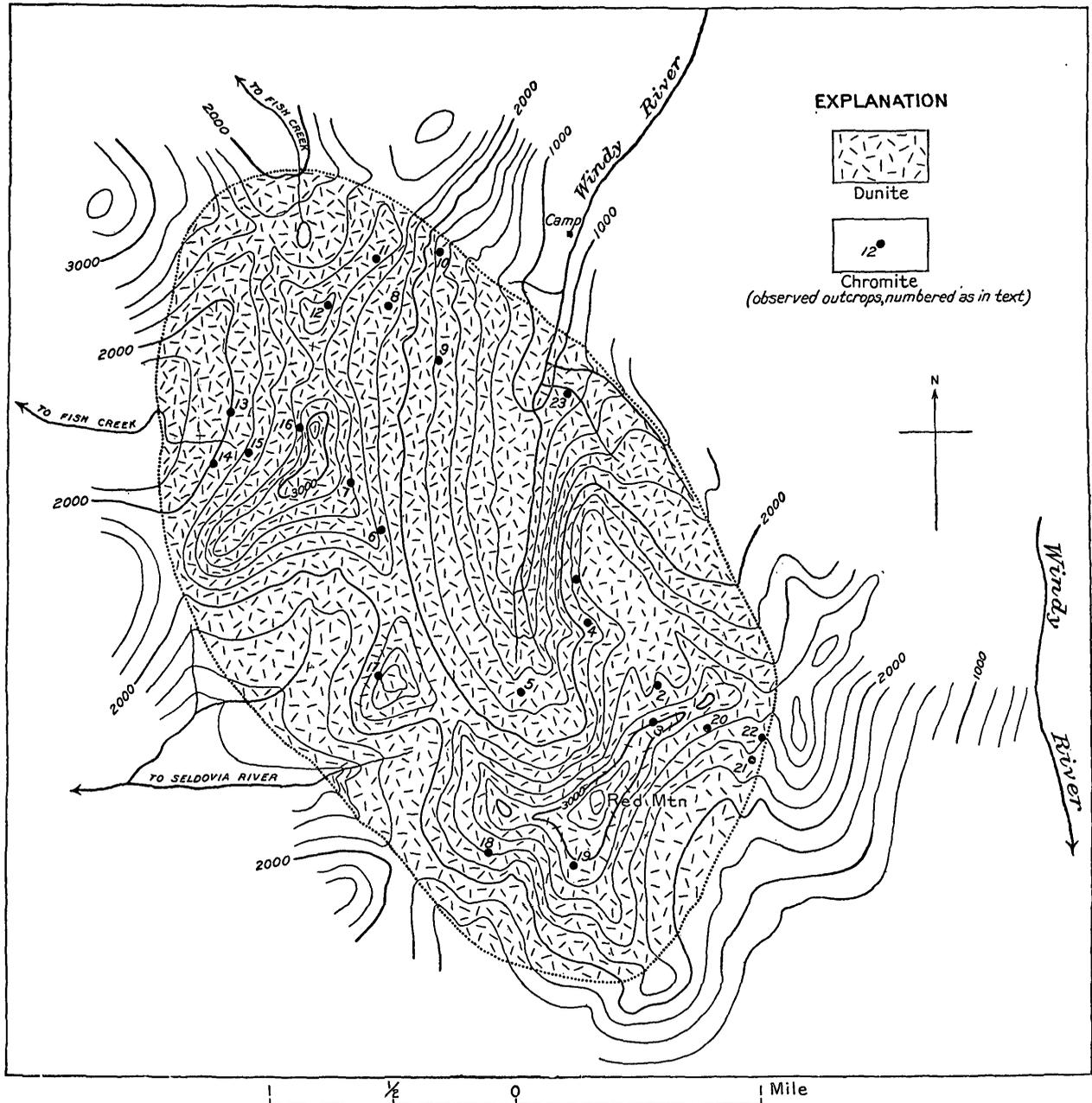
The ore bodies in the Red Mountain district seem on the whole longer and thinner than those at Port Chatham, less markedly banded but nevertheless of striking similarity in character. Descriptions of the salient features of the separate deposits will be given in the sequence of their location, following first around the inner basin at the head of Windy River and then around the outer slopes of the main ridge. The positions of these deposits are shown on Plate III.

1. At the northwest end of the high ridge that divides the main valley at the head of Windy River from the valley of its small tributary that flows along the dunite contact and parallels this ridge to the north is a chromite deposit on one of the Babcock & Martin claims.

Its altitude is about 2,300 feet, and the descent to Windy River to the northwest is precipitous. This occurrence is unique in that it is composed of two parts which appear to be of different origin. The heaviest part is an irregular mass of lustrous black chromite with cleavable green hornblende at both contacts and at some points in its interior. It has the strike usual in the chromite bands of this vicinity, about N. 10° W., but its dip is at a low angle to the east, instead of about 45° W., which is the prevailing dip. A sample was found to have a specific gravity of 4.46, with only 32.10 per cent of chromic oxide. (See p. 122.) This occurrence was noted in the field as probably recrystallized, and its variation in composition from the usual type was expected. ◦

The part of this exposure that conforms to the usual type is more uniform in thickness, reaching a maximum of a little more than 2 feet. It seems to be cut by the recrystallized vein, a part of the outcrop occurring at their intersection. From its bearing on ore genesis this deposit would deserve much more careful study. As a source of chromite, in view of the low tenor of the recrystallized ore, it is probably of minor importance, as its thickness decreases to about a foot within 40 or 50 feet.

2. The exposure of ore body No. 2 is by far the most extensive seen in the district. It is covered mainly by the mining claims located by F. A. Rapp for Whitney & Lass, known as Star Chrome No. 4. It is at an altitude of about 2,600 feet on a sort of ridge-ribbed plateau in the easterly angle of the main valley. It strikes N. 8° W. and dips 60°–70° W. A section at the discovery monument was measured as follows:



Contour interval approximately 200 feet  
MAP SHOWING CHROMITE DEPOSITS AT RED MOUNTAIN.

*Section on Star Chrome No. 4 claim at discovery monument.*

	Ft.	in.
Dark ore, mostly of shipping grade, containing 16 inches of silicate rock in five bands, the thickest of which is 6 inches-----	10	7
Rock-----	1	2
Black ore-----		4
Rock-----		5
Ore-----		5
	12	11

For 500 feet along the strike northward from the discovery monument the ore is in a trench or gully, doubtless excavated by glacial action on the less resistant chromite. Exposures are frequent enough, in spite of the loose material, to leave no doubt of the continuity of the ore for the whole distance, probably with only gradual variations in cross section. At 500 feet from the monument the section was as follows:

*Section on Star Chrome No. 4 claim north of discovery monument.*

	Ft.	in.
20 per cent ore-----	1	10
Mostly dunite-----		10
10 per cent ore-----		8
40 per cent ore-----	1	5
Rock-----		6
42 per cent ore-----		11
Rock-----	2	2
50 per cent ore-----	1	2
	9	6

For the next 200 feet northward on the ore the stringers get farther apart, but one rich band maintains a thickness of 6 to 14 inches for a distance of not less than 500 feet.

South of the discovery monument the chromite can be traced for 130 feet, to a point where it is reduced to a thickness of 18 inches of good ore. At about 50 feet from the monument there is an offset of 10 feet to the right, showing that faulting has occurred in this region.

Estimates of quality are based on the appearance of the ore. They seem to be corroborated by the specific gravity of 4.16 to 4.25 found for the richest specimens. The relative proportion of shipping ore here is judged to be unusually high. It may conservatively be placed at half the volume of the ore body.

3. At an altitude of about 2,950 feet, on the inner wall of the main valley, about 200 feet below the summit of the ridge, above the upper limit of the talus and nearly south from deposit No. 2, are many chromite stringers striking N. 30° W. and dipping 40° W. Two

higher-grade ore bands reach a thickness of 2 feet each. The low-grade material is mostly too poor to be considered workable. At the top of the ridge the ore was estimated by F. A. Rapp, who made the difficult ascent, to have a total thickness of 10 feet, of which 18 inches seemed to be of shipping grade, while the remainder was rated at 20 per cent chromic oxide.

4. West of north from deposit No. 3, at many points on the rough surface of the westward-tilting "plateau," are stringers of both high and low grade chromite which seem too small for separate mention, as a rule, though four lenses south and west from deposit No. 1 were noted as of shipping grade, with dimensions of 12 to 15 inches in greatest thickness and 10 to 20 feet in length. The dip and strike of the ore bodies in this region are in general somewhat parallel to the mountain slope, so that in many places a 1 or 2 inch layer of chromite simulates in appearance a heavy lens of ore through its exposure as a thin layer on a surface 2 or 3 by 8 or 10 feet. Of the lower-grade bands observed in this region only one seemed of sufficient importance for description. It is exposed for 100 yards or more along the south wall of the stream which drains this so-called plateau area, at altitudes of about 2,000 to 2,200 feet. Its continuity for the whole distance along the wall is probable, though it was seen over perhaps only half of the distance on account of the roughness of the surface and the necessity of passing close under the cliffs along the top of the talus slope, thus obscuring the view of the ore, if, as is thought probable, it was exposed. The thickness of this layer is somewhat more than a foot. It is faulted at several places, with displacements of a few inches to 3 feet. The grade of this ore is estimated at 15 per cent chromic oxide.

5. At an altitude of about 1,700 feet on the rocky spur that separates the main stream valley heading against the north slope of Red Mountain from the small brook that heads near the easterly pass to the Seldovia River drainage basin is a body of chromite on which the Horseshoe claim of Whitney & Lass is located. It is exposed for about 60 feet with a thickness of 1 to 3 feet. Fully half of it appears to be of shipping grade. It shows several small faults, one with a throw of about 3 feet, and ends so abruptly as to suggest faulting as the cause of its termination. To the north, diagonally downhill, are many small chromite stringers in the rocky stream beds for a distance of 300 or 400 yards. The largest of these, composed of low-grade ore, has a thickness of about 2 feet and is much contorted. This occurrence, which is at an altitude of about 1,400 feet, is accompanied by a crushed zone, so that there is much doubt whether it is a faulted continuation of the Horseshoe ore body or not. On the whole it seems more probable that it and the many intervening layers are in a position underlying the Horseshoe. The

lower ore bands strike about N. 20° W. and dip 75° SW. Above the crushed zone the dips are much flatter, as a rule, though very variable.

6. The rich but small ore lenses that occur near the two low divides to the Seldovia River basin lie in nearly horizontal position. The next deposit of sufficient importance to be mentioned is that on the Star Chrome No. 2 claim of Whitney & Lass, at an altitude of 2,300 feet on the northeast slope of the main ridge northwest of the western pass toward Seldovia. Good ore is exposed for a distance of 50 feet with a thickness of 14 to 24 inches. About 200 feet to the southeast is a 12-inch exposure of good ore which seems to be connected by low-grade stringers with the main mass. The ore here lies nearly horizontal.

7. At an altitude of nearly 2,500 feet on the same ridge with deposit No. 6 and in line toward the high dunite point on the west ridge is an exposure of 12 to 15 inches of good (40 per cent) ore with a foot of rocky material on each side of it which was judged to carry only 5 to 10 per cent of chromic oxide. Uphill this runs down to only 6 inches of good ore within a distance of 10 feet. If it continues to widen downward under the talus slope at this rate it may be a considerable ore body. The strike is N. 22° W. and the dip about 45° SW.

8. On the shelf or narrow plateau, which is seemingly a remnant of the old valley floor not removed by the glacier which deepened the center at an altitude of a little more than 2,200 feet and about half a mile south of the lowest pass to Fish Creek, is the deposit on which the Juneau No. 1 claim is located. Its strike is N. 58° W. and its dip 45° SW. At the southeast end of the natural exposure the cross section consists of 18 inches grading regularly from rock to shipping ore, 82 inches of good ore, and 12 inches showing gradation back to wall rock. About 100 feet southeast of this point a pit dug through about 3 feet of surface material uncovered the chromite with a width of 5 feet of banded and disseminated ore, half of which is estimated at 30 per cent chromic oxide, and the rest of poorer grade. The covering of the ore contained little or no chromite, indicating that it is not a result of weathering in place but was brought from less chromiferous localities by glacial action or hill creep. At 50 feet northwest of the heavy outcrop mentioned above the ore attains its maximum thickness of 12 feet, and at 30 feet farther in the same direction it comes to a sudden end. This is probably at a fault, as there are several small step faults in the 80 feet of exposure. Until the discovery of deposit No. 2, in July, 1918, this was considered the best body of chromite in the district.

9. The series of chromite layers described together under No. 9 would probably be classed as at least three separate deposits, and very likely more than that, if time had been available for carefully

working out all details observable in the exposures, which are located in the irregular cliffs southeastward from deposit No. 8 at altitudes of 1,200 to 1,800 feet. None of them presented a thickness of more than 3 feet of concentrating ore or 16 inches of high-grade ore in a single band. Such bands are locally within a foot or two of each other, however, so that if one were worked the other would doubtless also be taken.

The highest exposure, at 1,800 feet, consists of two bands with a total thickness of 4 or 5 feet of concentrating ore. They strike N. 20°-25° W. and have a westerly dip.

About 150 feet lower on the mountain side is a set of chromite stringers in a section of 25 feet, two layers in which attain a thickness of 1 foot each. This series of bands can be traced for a distance of at least 250 feet, up to an altitude of 1,900 feet, at which they pass to inaccessible cliffs where they can be seen for perhaps a hundred yards farther. They appear to pass under the Juneau No. 1 lode and are separated from it by a heavy pyroxenite band, which, like many smaller ones observed in this locality, is parallel to the ore stringers. They strike N. 6° W. and dip 45° W.

At altitudes of 1,200 to 1,400 feet near the base of the cliffs is a series of small high-grade chromite bands, approximately in parallel position under those just mentioned. The largest of these maintains a thickness of 8 to 16 inches for a distance of not less than 300 feet. How many of the associated smaller bands would pay for working is uncertain, but without question many of them would be utilized if the larger mass were mined.

**10.** The Juneau No. 4 mining claim of Whitney & Lass is at an altitude of 1,600 feet, 100 yards or so southwest of the small stream that heads against the Fish Creek basin at the dunite contact. The ore body is so near the contact that it is within the crushed zone, though not so completely broken up as the silicate rock nearer the boundary. Its thickness is somewhat variable, mostly 3 to 4½ feet, though at one point it pinches down to about a foot. Its length is not less than 250 feet. It ends abruptly at the top, doubtless at a fault, with a thickness of 2 feet exposed, while the north wall is obscured by débris, so that only this minimum thickness could be determined. At the lower end it passes under talus in which there are many chromite fragments for 100 feet or more. These may have fallen from the exposed portion. The chromite body strikes N. 82° E. and is practically vertical in dip. It seems to be largely of excellent quality, though its crushed condition renders its appearance somewhat abnormal.

**11.** A quarter of a mile south of the lowest pass between Windy River and Fish Creek is a heavy chromite band that apparently crosses the main ridge, which is here double for a considerable dis-

tance, the two parallel crests being some 150 feet apart. At the easterly crest excavation by F. A. Rapp in the crumbly chromiferous loose material uncovered the ore at a depth of about a foot with a cross section, beginning at the north, as follows: 30 inches nearly half chromite; 48 inches mostly rock; 84 inches good ore, of which at least two-thirds is of shipping grade. A hundred feet away down the mountain side to the east the ore has an easterly strike and nearly vertical southerly dip. Its section at this point shows 18 inches of shipping ore and 78 inches estimated at half chromite. About 20 feet higher this section revealed 72 inches of ore, at least half of it estimated to run 40 per cent chromic oxide or better. This deposit may have been originally a part of No. 9, above described, but the intervening terrain is with difficulty accessible, even where not covered with talus, and the relation was not proved.

Toward the west chromiferous float can be traced continuously to the top of the west ridge, whence a low grade band perhaps 3 or 4 feet in thickness can be seen in the vertical rock wall with a moderate dip—about  $45^{\circ}$ —to the south.

12. From deposit No. 11 the main dunite ridge runs due southwest for 500 or 600 yards to a culminating point which appears by aneroid determination to be almost exactly 3,000 feet above the sea. About 100 yards northeast of this summit three bands of chromite appear from blocks and fragments not exactly in place to cross the crest of the ridge. They are 50 to 75 feet apart and appear to have a thickness of  $2\frac{1}{2}$ , 5, and 2 feet, respectively. The larger one is thought to continue along the westerly slope of the ridge and to be identical with an ore body located by N. Clarberg for Whitney & Lass. He described it as on the back side of this mountain, and one of his monuments was seen at an altitude of 2,700 feet on the spur that runs from this peak and divides the two main heads of Fish Creek. The fog was so thick at the time of the writer's visit, however, that this identification could not be confirmed. The deposit is said to be 3 or 4 feet thick, mostly of rather low grade, and to dip south.

13 and 14. Deposits Nos. 13 and 14 are probably either parts of the same ore band or different bands in a closely related series. Both nearly follow the 2,000-foot level at the southerly head of Fish Creek, strike about  $N. 20^{\circ} E.$ , and dip at a variable angle, mostly much less than  $45^{\circ}$ , to the east. No. 13 is north of the main stream and can be followed along the mountain side for a distance of fully 500 feet. It is broken at many points by small faults. Its thickness ranges from 1 to  $2\frac{1}{2}$  feet of fair concentrating ore, with only a little that appears to be as rich as 40 per cent chromic oxide. Toward the north end there are three bands of chromite, each more than a foot thick in a section of 100 feet, one of which is probably

the continuation of this layer, though this continuity is established only by the occurrence of chromite of similar rather low grade in the blocks fallen from the cliffs. Still farther, about 500 yards south of the 2,100-foot divide, between the heads of Fish Creek, a portion of one of these ore bands shows 6 inches of nearly shipping grade underlain by 5 or 6 feet of poor disseminated ore. At this point the strike is N. 51° E. and the dip 55° SE. No. 14 can be followed for more than 400 feet, beginning near the main stream and following approximately the top of the talus slope toward the divide between Fish Creek and a branch of Seldovia River. Its thickness is nowhere less than a foot and in some places reaches 2½ feet. Most of it is only of concentrating grade, though in many places there is some high-grade material, at one point reaching a foot in thickness. The dip of the ore becomes flatter toward the south.

15. In the upper cirque at the head of the south branch of Fish Creek at an altitude of about 2,350 feet, southeast of the stream, is a band of chromite from 12 to 24 inches thick, which is estimated to carry 35 per cent chromic oxide. Toward the southwest it is cut off by a fault. About 50 yards distant and 30 feet higher than this faulted end are some low to medium grade stringers which are judged to be the continuation of the same ore body. To the northeast it passes under the talus with a thickness of 2 feet and with seemingly increasing magnitude. The main exposure is some 50 or 60 feet in length.

16. High in the wall of the cirque, about northeast of deposit No. 15, is a black mass that looks at a distance like very rich chromite. This appearance seems to be confirmed by the presence of high-grade float in large blocks at the foot of the inaccessible cliffs. The suggestion that this deposit may be a continuation of No. 15 is rendered plausible by the increasing dips of the chromite bands in that direction. The presence of a heavy pyroxenite band below raises the further question whether it may not also be a part of the ore stringer on which Juneau No. 1 claim is located (deposit No. 8), as that also seems to be underlain by a similar pyroxenite layer.

17. In the pyramidal peak between the two low passes from the head of Windy River to the Seldovia River drainage basin there is at least one chromite body of considerable magnitude. It is covered by a mining claim of F. P. Skeen. It is not well exposed on the north side of the mountain, though its nearly horizontal position and the presence of considerable chromite float, part of it very rich in appearance, would indicate its probable extension to that slope. On the northwest declivity, however, at an altitude of about 2,400 feet and just above the talus slope, it shows for a distance of some 350 feet. At its northern extremity it is cut off by a fault of unknown

but probably not great magnitude. For 60 feet it maintains an average thickness of 4 feet, then gradually frays out into a series of separated lenses to the south. There are several small faults, of which the largest has a displacement of about 6 feet, showing relative raising of the southerly block.

The ore contains some high-grade lenses but is chiefly of good concentrating type. Below this ore there is much more chromite in the talus blocks down to the 2,000-foot level than would seem likely to have been derived from a single layer of this magnitude, but no other was seen in place.

18. At an altitude of 2,400 feet on the southerly spur of the high point half a mile west of Red Mountain is a chromite body which strikes N. 24° W. and dips 35° SW. At its upper end, where it shows about 4 feet of fair concentrating ore, it is cut off by a fault. Downward it passes under the talus but reappears at a distance of some 120 feet with a cross section of 12 inches of rather rich concentrating ore, 30 inches of rock, and 20 inches or more (the lower wall is not exposed) of rich concentrating ore. Float at lower altitudes would indicate that the ore body continues down the spur with good quality and in considerable size.

19. On the spur running nearly south from the summit of Red Mountain, at an altitude of about 3,000 feet, is considerable low-grade chromite debris, indicating the locality where a very large ore body crosses the spur. The crest of the spur is marked by monuments as the dividing line between claims of F. P. Skeen and Babcock & Martin, Skeen and Babcock having made the discovery in common. The ore was not observed in place, as was expected, on account of the lateness of the hour when it was reached, though it had previously been seen from a distance near the top of the cliffs that constitute the flanks of the spur. Mr. Skeen states that it is the largest body of chrome ore seen by him at Red Mountain, the next largest being deposit No. 3.

20. At an elevation of about 2,600 feet on the southeasterly slope of the rugged ridge that runs northeastward from Red Mountain, just at the top of the talus and approximately a third of a mile from the pass (on the dunitic contact) between the upper and lower portions of the Windy River valley, is a body of banded chromite. Its thickness is 3 feet where it passes beneath the talus, and it can be seen to maintain a thickness of approximately 2 feet for 200 feet or more up the steep cliffs. It strikes almost exactly north and dips about 70° W. Near its lower end is an offset to the right of nearly 20 feet, and in the higher portion three or more faults of somewhat less magnitude can be seen. The ore was judged in the field to be better than half chromite. A sample taken to show its average quality was found to have a specific gravity varying from 3.73 to 3.87.

**21.** On the ridge that runs S.  $16^{\circ}$  W. from the pass just mentioned, at an altitude of a little more than 2,300 feet, are three small chromite deposits, covered by a mining claim of F. P. Skeen. The largest of these shows a thickness of 2 feet of ore that runs about 30 per cent chromic oxide for a distance of 8 feet. The smaller deposits, just above this one, are of better grade but have thickness of only about a foot. All three are apparently terminated by faults.

**22.** In the bed of the small stream that flows near the dunite contact 100 yards or so northeast of deposit No. 21, at an altitude of about 2,460 feet, is a mass of chromite which lies within the outer crushed zone of the dunite. It is much slickensided and shows a thickness of 2 to 4 feet for about 30 feet. The ore is of good quality, but its crushed condition renders comparison with the ordinary ores of doubtful value. The character and distribution of loose material suggest that the ore continues for some distance, perhaps 100 feet, downstream from its lowest outcrop.

**23.** At an altitude of 1,100 feet in a shallow gully near the smaller (southerly) of two streams that flow northwestward into Windy River through the valley caused by erosion of the softer rocks at the dunite contact are large blocks containing at least 7 or 8 tons of excellent chrome ore. In one block the cross section showed 16 inches of 40 per cent to 50 per cent ore, 5 inches of waste, and 7 inches of ore of the same grade as the thicker layer. About 100 feet to the northeast in the stream bed are three 1-foot stringers of low-grade chromite striking N.  $22^{\circ}$  W. and dipping about  $60^{\circ}$  SW. Whether the blocks were derived from the same ore body that appears in the outcrop is doubtful, but they are certainly near the same position and indicate either an improvement in the quality of the ore along the strike or the presence of a second deposit of some importance.

Streams, glaciers, and frost have moved loose rock fragments so widely that it is doubtful if an acre of fragmental rock in the Red Mountain dunite area could be found without macroscopic chromite stringers at the surface. Yet there are many places where unusual accumulations leave no doubt that a workable chromite ore body is near at hand. There are also localities where rich fragments occur in such a manner as to show that good ore extends for a considerable distance without evidence that its thickness is sufficient to render it workable. Some of the most promising of these are occurrences described below.

From a point just south of the pass between Windy River and Fish Creek down the steep talus slope toward Windy River there are numerous flat chromite fragments, mostly under 3 inches in length. They extend for at least 200 feet. The best of the ore is mottled and has the composition shown in analysis No. 6, page 122.

A hundred feet below this pass, on the Fish Creek side, occur some scattered blocks and fragments of high-grade, much slickensided chromite in the soft-weathering contact zone. These continue for a distance of more than 300 yards downward, varying in abundance and reaching about a foot in maximum size.

On the ridge between the two heads of Fish Creek, about 150 yards west of its lowest point, is much brownish porous-looking chromite (analysis No. 5, p. 122) in blocks up to a foot or more in size. The small fragments extend down both slopes of the ridge for 200 or 300 feet. Their abundance indicates a very large ore body, though a little digging in the soft chloritic contact rock failed to locate it. On the same ridge, less than a hundred yards S. 25° E. from the low pass, are many small ore fragments indicating a fair-sized ore body of excellent quality. The fragments continue less abundantly and of poorer grade upward along the ridge to the southeast for 200 or 300 yards farther.

Large blocks of high-grade ore occur in the moraine at an altitude of some 2,000 feet just north of the main southerly branch of Fish Creek. These may have come from deposit No. 16, seen in the cirque higher up, but are so abundant as to suggest a much nearer source, as they would probably have become more scattered in traveling so far on the ice.

In the pass between Fish Creek and the Seldovia River basin on the dunite contact at an altitude of 2,100 feet there are a good many rich-looking chromite fragments as much as 6 inches in diameter. They extend some distance downward along the contact on the Seldovia River side, but if present on the slope to Fish Creek they are covered by a large snow bank and talus from above. Similar occurrences were observed at the dunite contact at several points southwest and south of Red Mountain.

Near the discovery monument of F. P. Skeen's Big Chrome No. 1 claim, at an altitude of 1,500 feet in the contact valley which slopes northwestward to Windy River, are very abundant chromite fragments 2 or 3 inches in length and estimated to contain 30 to 45 per cent chromic oxide. These fragments doubtless mark a considerable ore body.

Only three occurrences of chromite float in the inner basin of the Red Mountain ridge will be mentioned, though many more of less extent were seen. Two of these are thought to be very probably derived from ore bodies in place, already described. They are both on the rough surfaced plateau on which deposits Nos. 1 and 2 are situated. One of them consists of widely scattered high-grade blocks from a few pounds to half a ton in weight, some lying on bare dunite and some piled with other detritus, seemingly carried northward from deposit No. 2 by glacial action. Many tons of excellent ore could

be gathered from the surface. The other one occurs at the southwest edge of the plateau along its southerly half and consists of immense blocks of dunite, in which are many stringers of banded chromite. One block, 25 or more feet long, perhaps from deposit No. 3, was cut by a 3-foot layer of concentrating ore estimated at 20 per cent chromic oxide. A mixture of high-grade and low-grade ore in abundant blocks occurs at an altitude of 1,600 to 1,700 feet on the slope N. 51° E. from the pyramidal mountain between the low passes toward Seldovia. The larger blocks show at least 6 feet of concentrating ore, and some of the smaller masses a foot of fair shipping ore.

The quality of the Red Mountain chromite has not been investigated with any degree of thoroughness, though much material has been collected upon which such a study might be based. Analyses made by Chase Palmer in the chemical laboratory of the United States Geological Survey at the writer's request were directed to the determination of  $\text{Cr}_2\text{O}_3$  in the aberrant varieties, as the great similarity to the Port Chatham material, combined with the high percentage reported by Grant<sup>1</sup> on a chromite from this area (the exact locality is not stated), leaves no room for doubt as to the general quality of the ore. Mr. Palmer's results, together with field estimates on the same specimens, are as follows:

*Analyses of chromite ore from Red Mountain.*

No.		Specific gravity.	$\text{Cr}_2\text{O}_3$ (per cent).	
			Found.	Estimated.
4	Recrystallized chromite.....	4.46	32.10	60
5	Porous ore.....	3.93	48.89	50
6	Mottled ore (porous).....	3.59	41.93	30

Of these specimens No. 4 does not appear to contain any foreign material. It is from the recrystallized part of deposit No. 1. It shows a great divergence from the magmatic ores in chromic oxide content and its slight attraction by the magnet would suggest a high percentage of iron. Analysis No. 5 was made on material from the pass between the heads of Fish Creek, and No. 6 on a specimen from the main ridge at a point 100 yards south of the lowest divide between Windy River and the north branch of Fish Creek. These two analyses indicate that the somewhat spongy texture is no indication of inferior ore. The porosity may be due to removal of some

<sup>1</sup> U. S. Geol. Survey Bull. 587, p. 238, 1915; 57 per cent  $\text{Cr}_2\text{O}_3$  is given as the result obtained by C. E. Bogardus.

of the interstitial silicate. The impurity seems to be olivine in the mottled ore and is very likely the same mineral in the other porous specimens.

## TONNAGE.

Calculations of the amount of chromite in the Red Mountain deposits were made on the same basis as for those at Port Chatham (p. 110). This method of estimate assigns a very large tonnage to the deposit on Star No. 4 claim—in fact, so much larger than to any others in the region that some hesitation is felt about its accuracy. However, the excellent exposure of this deposit at the surface leaves no doubt as to its longitudinal extent, so that it would be quite as reasonable to infer that the longitudinal dimension of the other deposits has been underestimated on account of poor exposure or of faulting as to assume an overestimate of depth for the Star No. 4 ore body, merely on the basis of inequality in size. On the whole, the alternative of low estimates seems more probable, though the factor of uncertainty as to depth should never be lost sight of in considering the significance of these tonnage figures.

Exclusive of those masses which do not appear to contain more than 500 tons, because this amount is within the limit of probable error of the larger numbers, the following table brings together the detailed estimates for the larger deposits:

*Estimated quantity of chromite ore as calculated from the observed dimensions, in tons.*

No.	Shipping ore.	Concentrating ore.	Chromite in concentrating ore.
2.....	90,000	80,000	32,000
3.....	5,000	25,000	10,000
4.....		5,000	1,500
5.....	250	1,500	600
6.....	250	2,000	600
8.....	10,500	6,000	2,500
9.....	5,000?		5,000?
10.....	8,000	5,000	3,000
11.....	7,000	16,000	8,000
12.....		10,000?	4,000?
13.....		22,000	6,600
14.....	1,000	14,000	4,200
17.....	1,000	16,000	6,400
18.....		3,000	1,800
19.....	(?)	30,000?	12,000
20.....		6,500	3,200
	128,000	242,000	101,400

Assuming, as before, a recovery of two-thirds of the chromite in the concentrating ores, we find that the estimate of total exportable ore in the Red Mountain district becomes 195,600 tons.

## MINING AND SHIPMENT.

No mining operations other than exploratory work have been carried on at Red Mountain. Even the route of shipment has not yet been decided upon by the holders of chromite claims, though Whitney & Lass devoted a good deal of effort during the summer of 1918 to finding a feasible route for transportation of loose or readily accessible ore in case insistent demand should arise.

## CONCLUSIONS.

## AMOUNT OF ORE.

The amount of ore above sea level at Port Chatham, on the assumption that material containing 10 per cent of chromic oxide can be profitably concentrated, has been estimated at 32,300 tons. Below sea level there may well be a much greater amount, as the lower deposits are as a rule richer and heavier than those at higher altitudes, which is in accord with the theory of settling in a molten magma. But even by the same process of calculation that was used for the ore above sea level, the exposures examined lead to an estimate of 12,600 tons below tide. The availability of ore below water level is extremely problematic on account of the great prevalence of jointing in the dunite. These joints are so open as to constitute a serious menace of mine flooding.

The amount of chromite in sight at Red Mountain is placed at 195,600 tons. This is a minimum figure, for no estimate was made of the quantity of ore in those deposits of indeterminable size whose existence is indicated by very rich float at eight or ten widely separated localities, nor has any account been taken of the large area covered by talus and morainal detritus, which presumably is as rich in chromite as the exposed areas. If this last presumption were made a basis for calculation it would at least double the estimate of chromite present, for more than half the dunite area is covered by loose rock.

It should perhaps be emphasized that one main feature of these deposits which lends uncertainty to the estimates of quantity is their tendency to divide, along their strike, into parallel bands, grading thus into immense low-grade masses in which the dimensions of workable material can not be defined. Such deposits are either excluded from the computations or are assigned only such size as is indicated by the relatively homogeneous portions.

## METHODS OF MINING.

The unusual persistence or continuity of the Kenai Peninsula chromite bodies promises to render a deviation from the open-pit

method of working both feasible and ultimately necessary. Cross-cutting at levels much below the outcrop may be found to save hoisting of the ore and to reduce the distance from mine mouth to shipping point. One obstacle to underground mining will doubtless be the occurrence of numerous faults, though some localities have suffered much less faulting than others. In planning mining operations it should be borne in mind that in those places where the strike of the faults nearly coincides with that of the ore bodies, as near the Star No. 4 prospect at Red Mountain, continuity in depth may be much less than along the surface, though extension in depth is to be expected when the continuation is located.

As an emergency procedure the gathering of scattered fragments of ore at the surface in the Red Mountain district might furnish several hundred tons. The sands at Claim Point and some stream gravels near Red Mountain suggest the further possibility of washing, though only on a relatively small scale.

#### CONCENTRATING.

So long as chrome ore containing 40 or 45 per cent of chromic oxide is marketable, it will doubtless pay to continue the present process of hand sorting except for the few deposits that may be found to yield ore rich enough to ship as mined. But there will always be a by-product of low-grade ore which must be handled even if it is not utilized. There are also large masses composed chiefly of low-grade ore which would not repay the cost of exploitation if only the shipping ore were marketed. Much of this material, say that running above 10 per cent chromic oxide, will doubtless prove profitable to concentrate by washing. Concentration has been found feasible at several of the Canadian deposits, where, however, serpentine instead of olivine seems to be the chief impurity. At Claim Point a milling plant is being installed, after a series of tests conducted in one of the mills regularly operating on gold ore near Juneau. This milling project has been undertaken at Claim Point even with the necessity of pumping or of bringing water across the bay from the creek to the north. At Red Mountain the water supply is ample up to an altitude of 1,200 or 1,500 feet. On the whole it may be estimated that one-half to three-fourths of the available tonnage of chromite in this region would require concentration, and if it shall be found that ore carrying less than 10 per cent chromic oxide can be profitably milled, the tonnage of available chromite will be much greater than these estimates, though, of course, the percentage suitable for direct shipment would be less than suggested.

Experimental determination of the relative behavior of olivine, pyroxene, and serpentine under mill tests would be of much practical interest. In the light of present experience economic handling

of these deposits would seem to require the installation of concentrating machinery.

The spongy and friable ores will doubtless lend themselves readily to crushing, though the problem of slimes may prove troublesome, especially in ore from the shattered areas.

The recrystallized chromite and possibly some of the original mineral can not be brought by concentration to a high content of chromic oxide, for the chrome-bearing mineral, even when in a pure, unmixed state, is a low-grade ore.

#### TRANSPORTATION TO TIDEWATER.

At Port Chatham the problem of reaching tidewater is simple. The new tramway promises to suffice for the large deposit on the northwest slope of Claim Point hill. For the higher deposits on the northerly side of the hill an extension of this tramway system may be found satisfactory, though the alternative procedure of tunneling from a point near tide level, entering the high sea wall at the northeast bight, is suggested by the possibility that the chromite stringers exposed in this cliff are continuous with those in the higher pits. At any rate the lower ores can be taken out in this way until they cease to repay working, when it may be possible to form a more definite opinion as to their connection with the upper deposits. All other known ore bodies at this locality are practically at sea level or below it.

At Red Mountain the transportation problem is much more difficult. In fact, it is a group of problems, for the chromite occurs at both high and low altitudes on the inside of the horseshoe ridge and also at many disconnected points on its outer slopes. It seems probable that concerted planning by all the holders of chromite properties in the region would be in the interest of ultimate economy, though only further development of the deposits combined with accurate surveys of the possible routes can furnish a really sound basis for a final decision as to outlet. Practical miners who have studied the situation seem to agree that the aerial tram promises to be the best means of making the initial descent from the higher ore bodies toward tidewater. It is possible here, however, as was suggested in the discussion of Claim Point, that if some of the lower deposits are worked first they may furnish underground access to those at greater altitudes. Though sufficient data may not be at hand for making final decision as to the best approach to water transportation, some of the features of the various routes may be compared.

Tutka Bay has excellent depth of water and is only 6 miles from the inner basin of the Red Mountain Ridge. The route to it would lead down the open valley of the northward-flowing portion of

Windy River for  $2\frac{1}{2}$  miles, then over a low divide estimated to be at an altitude of about 800 or 850 feet into a canyon-walled head of Jakolof Creek. Whether the east wall of this canyon would be as difficult as the west wall is more or less a matter of conjecture, but it appears to be easier as seen from below. The approach to Tutka Bay after reaching the low, flat land is also somewhat of a problem, as the natural opening through the ridge that follows the southwest shore of the bay is narrow and steep walled.

Jakolof Bay is at about the same distance from the dunite area as Tutka Bay. The upper part of the route to it would be identical with that of the Tutka Bay route except as facility in the lower course might indicate a different location higher up. The Jakolof roadstead is more rocky and shallow, however, which might necessitate a longer road to navigable water.

Fish Creek, entering Cook Inlet at Barabara Point, would lead to any depth of water that might be desired at the dock terminal. It touches the chromiferous rock at two places on the outside of the ridge. As seen from above, the valley of this stream looks passable for a road after the first steep descent over glacial débris has been accomplished. The distance is approximately 8 miles. This route would serve three or four good deposits of chromite but is cut off from the inner basin by a ridge more than 2,600 feet in altitude, except by the roundabout way of the headwaters of Seldovia River, where there are two passes at a height of less than 2,200 feet.

Seldovia Bay has the advantage of a well-charted harbor and a populated town. The route from this point to Red Mountain would reach dunite at an elevation of 1,200 to 1,400 feet above sea level. Its length would be 8 miles or more. The two passes to the inner basin are at an altitude of about 2,150 feet. The lower part of this route is said to be along a very steep rocky mountain side. Its upper end is over alternating flats of glacial boulders and rather steep rock or talus slopes.

Rocky Bay appears to be excluded from consideration by the extremely dangerous character of its harbor, coupled with the fact that Port Dick is equally accessible from the landward side and incomparably safer by water.

Port Dick has deep water within a mile of the head of the bay. The configuration of the bay is such that tidal currents are moderate for this region. The valley of Port Dick Creek leads to that of Windy River over a flat divide estimated at 100 feet above sea level. This estimate is based on an aneroid reading of 75 feet at the flat sphagnum meadow near the head of the creek, together with the observation that no dividing elevation was discernible from a height of 400 or 500 feet on the mountain slope north of the meadow. The

Port Dick route would reach the southeast end of the dunite area with a length of about 8 miles, having easy grades to the point where an aerial tram might set down ore from the two or three outer deposits which it would directly approach. Grades would be moderate also by way of the Windy River valley around to the inner basin, but the distance would be 7 or 8 miles more, and there is said to be a steep-walled narrow canyon with at least two waterfalls in the middle of this route.

The suggestion may finally be made that an ore road at an elevation of approximately 2,000 feet around the outer slopes of the dunite might connect all the peripheral ores with Barabara Point, Seldovia, or Port Dick, while connection with the inside might be made over one of the 2,150-foot passes to the Seldovia River valley or possibly by a tunnel on pay ore at any one of the several lower chromite bands. The northerly head of Fish Creek would seem most promising for the latter method of development if it were to be considered at all.

Investigations by Whitney & Lass into the possibility of an inexpensive wagon road for emergency shipment from the inner side of the horseshoe ridge, where the best of the known chrome deposits are situated, led to an adverse conclusion, on account of the steepness of the canyon walls and the occurrence of waterfalls both along the course of Windy River and along the small streams entering Jakolof Bay with low divides to the Windy River basin.

#### SHIPMENT AND MARKETS.

Ocean freight rates will doubtless be a permanent factor in the Alaskan chromite production, as the lack of a local market is likely to continue indefinitely. With these rates as at present, \$3.50 a ton to Seattle, it seems probable that the expense of delivering Kenai ore at Pacific coast points need not be greater than that for ore from many of the California and Oregon deposits.

The location of some of the Kenai deposits at or near tidewater, where the ore can be cheaply loaded into ocean-going vessels, gives them an advantage over the California deposits, most of which are in mountainous districts remote from the coast—an advantage that compensates in part, at least, for their greater distance from American markets. While it is still uncertain whether any chrome ore mined in the United States or Alaska can successfully compete in peace times with chrome ore from Rhodesia and New Caledonia, the outlook for the Kenai deposits appears to be at least as favorable as for those of California and Oregon.

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