DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 742

CHROMITE OF KENAI PENINSULA ALASKA

BY

A. C. GILL

WASHINGTON
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CONTENTS.

ILLUSTRATIONS.

CHROMITE OF KENAI PENINSULA, ALASKA.

By A. C. Gill.

INTRODUCTION.

Geographic relations of the area.—The region with which this report deals is near the intersection of the sixtieth parallel of north latitude with the one hundred and fiftieth meridian of west longitude. So far as is definitely known, the deposits of chromite it contains are restricted to two areas of basic igneous rock, chiefly of the variety of peridotite known as dunite, near the southwestern extremity of Kenai Peninsula. (See Pl. I, p. 4.) One of these areas forms a rocky hill called Claim Point, which stands at the entrance to Port Chatham, where the town site named Chrome was located in 1918, and extends for a short distance on to the adjacent mainland of the peninsula. It is thus practically at tidewater. The other is 16 miles to the northeast. Its culminating point is Red Mountain, the top of which, according to aneroid determination, stands at an altitude of 3,450 feet above sea level. The lowest point on the boundary of the dunite mass is a little more than 900 feet above sea level. Here the headwaters of a stream locally known as Windy River flow first northward and farther down swing eastward about 2½ miles north of the dunite area and then flow in a moderately direct southerly course into Rocky Bay. At other points on its periphery this mass of dunite is accessible at altitudes ranging from 1,300 to 2,000 feet by two heads of Fish Creek, which flows northwestward to Barabara Point, by two southward-flowing tributaries of Seldovia River, or by two short streams that run eastward into the lower reaches of Windy River. The distance from this deposit of chromite to tidewater at Tutka Bay, Jakolof Bay, Seldovia Bay, Rocky Bay, or Port Dick is 5 to 7 miles.

Mining operations.—Chromite has been mined commercially only at Claim Point, where nearly a thousand tons was mined in 1917 and about the same quantity in 1918, forming the entire contribution of Alaska to the chromite industry.

Previous investigations.—Grant, who visited both areas in 1909, noted the character of the igneous rock and mentioned two of the chromite deposits. He reported also an analysis of the richer chromite from Red Mountain.[1]

In the summer of 1917 J. B. Mertie, jr., of the United States Geological Survey, gathered data, some of which have been published,[2] concerning the deposits of chromite at Claim Point and Red Mountain. Mr. Mertie very kindly placed his field notes at the disposal of the writer of this report.

W. P. Lass, of Whitney & Lass, who own and operate the property at Claim Point, has published a statement showing the quantity, quality, and conditions of shipment of their product for the season of 1917.[3]

Investigations made for this report.—During the season of 1918 the writer, assisted by W. Brooke Graves, made a more detailed study of these chromite-bearing areas, spending the period from July 2 to August 25 in making investigations of the known deposits, in searching for others in adjacent regions, and in making examinations to determine whether nickel or platinum may occur in association with the chromite. These investigations and others suggested by the results of the field work have been by no means finished, but such observations as seem to have a bearing on the quantity, occurrence, and exploitation of the chromite of Kenai Peninsula are here presented. A preliminary report on these investigations was published in 1920 (U. S. Geol. Survey Bull. 712, pp. 99–129).

Acknowledgments.—Acknowledgment should be made of the aid in the preparation of this report that has been given by the owners of the chromite properties, as well as by several members of the United States Geological Survey in Washington and by the writer's colleagues at Cornell University. Special aid has been rendered in the field by Capt. G. H. Whitney, Mr. W. P. Lass, Mr. F. P. Skeen, and Mr. F. A. Rapp.

GEOLOGY.

GENERAL FEATURES.

The country rock in which the chromite is found is here broadly called dunite, though some of the local varieties of it might be more specifically called by other names, and parts of it have been weathered to serpentine.

The rocks are of igneous origin and are surrounded by more or less metamorphosed clastic beds like those which in adjacent regions have been termed by Martin[4] slates and graywackes, and by Grant[5] graywacke and slate, with chert, limestone, and volcanic

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[1] 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.

[2] Mertie, J. B., jr., U. S. Geol. Survey Bull. 692, pp. 265–267, 1919.

[3] Lass, W. P., Chrome deposits of Alaska: Min. and Sci. Press, vol. 115, p. 653, Nov. 3, 1917.

[4] Martin, G. C., and others, op. cit., p. 44.

[5] Idem, p. 227.

material. Both these investigators regard the age of these sedimentary rocks as somewhat doubtful but as probably Paleozoic or early Triassic. No attempt was made by the writer of this report to investigate their complicated structure, though observations were made as opportunity offered. All such observations, some of which were made on outcrops presumably not hitherto visited by geologists, confirm the conclusions reached by previous observers that they show a general northerly to northeasterly strike and a complex structure.

The relation of the dunite to the inclosing metamorphic rocks was repeatedly considered during the field examination, but no absolutely conclusive evidence of their relative ages was found. The natural assumption that the dunite was intruded as a magma into the graywacke series should be accepted without much doubt, but alternative possibilities should be kept in mind. For example, solidified dunite may have been thrust upward through overlying beds or may have passed to lower geologic horizons, either by its greater specific gravity or by the relative elevation of the surrounding rocks by orogenic forces to which the dunite was more resistant. A suggestion that the rock masses now in juxtaposition with the dunite did not at all places constitute the inclosing walls while the magma was crystallizing may be seen in the lack of dikes or apophyses cutting into the adjacent sediments; in the extreme brecciation and slickensiding, which show a differential or slipping motion of the outer zone of the igneous masses, though their inner parts consist of angular joint blocks; and in the very slight indications of contact-metamorphic action, not necessarily more than might result from the heat developed by the mechanical crushing. On account of their theoretical interest the questions suggested would repay a more detailed study than it was possible to give them in connection with other field investigations.

Glacial and alluvial phenomena are widely manifested in this region. Their relation to the chromite deposits may be seen in both the covering of bedrock at some places and its exposure at others, in the transportation of dunite or chromite "float," and in some of the topographic features which determine or modify problems of transportation.

The flat, low land near sea level, partly grassed and partly wooded, which lies between Claim Point Hill and the mainland of the peninsula, is doubtless composed of gravel, as waves and tidal currents have exposed no hard rock. It is probably a remnant of an alluvial fan, the outwash from a vanished glacier which occupied the main Port Chatham Valley, to the east. This gravel may be said to cover the dunite contact, though the contact probably lies below the water level.

THE ROCKS.

METAMORPHIC ROCKS.

The metamorphic rocks have been described by Martin, Johnson, and Grant.[6] They include black slate, chert containing quartz veinlets, graywacke composed of sand or arkose, and graywacke containing lenticular layers of carbonate with included shale fragments or with a decided aspect of " greenstone."

These rocks are in general but slightly altered near the dunite—certainly much less than lithologically similar rocks at their contacts with the diorite near Point Bede and south of the entrance of Koyuktolik Bay.

DUNITE MASSES.

PORT CHATHAM.

POSITION, SIZE, AND SHAPE.

The Port Chatham dunite mass is so nearly surrounded by water that its exact boundaries and dimensions can not be given. (See Pl. III, p. 18.) It doubtless forms Claim Point Hill, as 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 underlies also these grassy flats, a part of which forms the narrow neck connecting Claim Point with the mainland of Kenai Peninsula, and it is exposed along the base of the mountain on the mainland at many points, the most widely separated of which are three-fourths of a mile apart. The dunite is not seen along the base of the main ridge west of the neck, though the metamorphism of the rock just west of the junction of the gravel neck with the mainland may indicate its proximity. The extreme observed distance between actual exposures from east to west is almost a mile. From north to south the distance is seven-eighths of a mile. The actual dimensions of the dunite area are of course greater than this, perhaps nearly as shown on the accompanying map (Pl. III).

INTRUSIVE RELATIONS.

No decisive evidence that the dunite was intruded into the graywacke series is observable at Port Chatham, but there are some indications of such intrusion. At the angle in the shore line on the mainland just west of the neck of timbered gravel flat connecting it with Claim Point Hill there is an exposure of considerably metamorphosed greenstone like graywacke, containing many silicified lenses, several of which show a cross section 3 or 4 feet long and nearly

[6] Geology and mineral resources of Kenai Peninsula: U. S. Geol. Survey Bull. 587, 1915.

GEOLOGIC RECONNAISSANCE MAP OF THE SOUTHWESTERN PART OF KENAI PENINSULA, ALASKA

Alfred H. Brooks, Geologist in Charge of Division
Topography by R. H. Sargent, D. F. Higgins, and from sketches by G. C. Martin and A. C. Gill.
Geodetic position and much of the coast line from data by U. S. Coast and Geodetic Survey.
Surveyed in 1909, 1911, and 1918.

Scale $\frac{1}{250,000}$

5 0 5 10 15 Miles

5 0 5 10 15 20 Kilometers

Contour interval 200 feet.
Datum is mean sea level.
Dashed lines represent probable topography of unsurveyed areas

1922

Geology by A. C. Gill, U. S. Grant, and G. C. Martin
Surveyed in 1909, 1911, and 1918

1 foot wide. A few specks of what looks like pyrrhotite appear in these rocks. A similar lenticular silicification has occurred in the slates and cherts near the eastern edge of the dunite—also on the mainland of the peninsula. Here many spots of limonite appear in the rock, but no fresh sulphide was observed, though it was sought at several rusty exposures. The appearance of these minerals may very well be considered evidence of contact metamorphism, which is often noted as less intense about dunite areas than about more siliceous intrusive rocks.

The brecciated rock at the base of the mainland ridge just at its easterly junction with the Claim Point neck contains angular fragments of chert and graywacke together with dunite. It may be a contact breccia formed by the intrusion of the peridotite.

The lower slopes of the mainland ridge are so densely covered with grass and trees that the contact phenomena as well as the location of the contact are hidden.

DEFORMATION.

The dunite has doubtless been subjected to most of the orographic stresses that have folded, faulted, and tilted the adjacent bedded rocks, but the effect produced seems to have been somewhat different on account of the greater resistance of the igneous rock to flexure. As a result it is almost universally jointed and faulted. Unequivocal evidence of faulting may be seen in the small offsets in the stringers or bands of chromite, which here have high angles of dip. The amount of lateral displacement ranges from a fraction of an inch to 30 or 40 feet. The vertical differential movement is usually much greater than the horizontal. The direction of striae on slickensided surfaces at the Reef mine indicates that it was five to ten times as much. In fact, Mertie in his unpublished notes described "some faults" at this mine as "slightly displacing the ore and others not at all," indicating that the fault throw was nearly or quite parallel to the intersection of the fault plane with the layer of chromite. Faulting is so widespread that the citation of special localities would be too onerous for both writer and reader, but the excellent exposure at the high sea wall facing the northeast furnishes an unusually striking example. Here a 3 or 4 foot zone of chromite stringers is broken into four or five blocks, with lateral displacements of 2 to 10 feet.

Those who attempt underground work on the chromite at Claim Point should remember that practically all observed lateral displacements of the ore are toward the right, although the vertical component of the movement is relatively downward on the westerly block.

A more profound fault may account for the shattered and highly serpentinized zone that extends northwestward from the base of the high sea cliff northeast of Claim Point Hill. The angular outline of the dunite area at its northeastern extremity is also possibly due to faulting.

WEATHERING.

The frequently observed barrenness of soils derived from highly magnesian rocks finds only partial exemplification at Claim Point. The higher parts of the northerly slopes are somewhat bare of vegetation, but the lower parts carry an abundant and varied flora. On the south side trees grow to the summit. This more luxuriant vegetation is very likely due to the glacial deposition of soil-forming detritus from other rocks, as the bare dunite seems to develop a plant covering very slowly, and glacial till is actually exposed at several points where the vegetation has been removed, notably in excavations for the tramway on the lower northwest slope and in the well at the Reef mine camp. Other weathering phenomena are better exemplified at Red Mountain.

RED MOUNTAIN.

SHAPE, SIZE, AND POSITION.

The area of dunite on Red Mountain is somewhat elliptical in shape (see Pl. IV, p. 30), being about 4 miles long from northwest to southeast, and 2 miles wide. Its area is approximately 7 square miles. The main summit of Red Mountain, which is near its southeast end, forms part of a dunite ridge that is shaped like a somewhat distorted horseshoe opening toward the north through the valley of Windy River. The boundaries of the igneous mass may be rather closely followed with the utmost readiness, uncertainty arising only at the outlets of cirques where former glaciers have deposited their load of material torn from the highly jointed dunite. Except by the roundabout course of Windy River the outer slopes of the horseshoe ridge are inaccessible from the inner basin at altitudes less than 2,150 to 2,700 feet. Transportation to tidewater thus becomes a very different problem for the different parts of the area, though the distance to be traversed may be nearly the same.

INTRUSIVE RELATIONS.

At Red Mountain, as at Port Chatham, only one possible apophysis of peridotite into the adjoining rocks was found, but there is a well-developed contact zone, which lies mainly within the igneous area. The actual contact shows a jagged surface, as if both rocks were solid at the time of their last differential motion. Brecciation and slickensiding have thoroughly comminuted the rock. In the field some of the hard brown brecciated material seemed to consist of crushed carbonate lenses of the graywacke, but laboratory investigation shows that chromite is one of its constituents, so that it is probably shattered dunite which has been carbonated. Qualitative chemical examination showed that this material is chiefly a carbonate containing much magnesium and iron and some calcium. This zone within the contact and adjacent thereto is much more highly serpentinized than the interior of the igneous area. The greater alteration seems due partly to the fact that it is greatly crushed and partly to the fact that the hydrating waters came from the surrounding rocks. A rather high temperature also probably tended to produce rapid serpentinization. The change to serpentine if once begun would, by the expansion in volume incident to hydration, undoubtedly accentuate the fracturing and slickensiding.

The wall rock into which the igneous mass was intruded has more the appearance of having been changed by mechanical action than by high temperature, as there is much slickensiding but no megascopic recrystallization.

The serpentinized contact zone ranges in width from a few hundred feet, its width in most places, to nearly half a mile, a width it reaches between the two heads of Fish Creek. It is found around the entire circumference of the dunite where bedrock is exposed, though it is much modified in character where pyroxenite instead of dunite is the material involved.

The hypothesis is suggested that explosive forces shattered this outer zone, probably before the interior was solidified, and that serpentinization and regional pressure, owing to its weakened condition, completed the crushing process and possibly caused differential motion on a larger scale. Water from the surrounding sedimentary rocks may have aided in the weakening of this zone as well as in its hydration.

DEFORMATION.

If the assumption is made that the bands or layers of chromite were deposited by gravitation from a molten magma it follows that they were originally nearly horizontal except where they may have been laid down on a sloping floor. Their present high angles of dip may be due either to tilting or folding by regional pressure or to magmatic flow. The former explanation appeared at first most probable, and in some places it certainly seems to apply, but the difficulty of explaining several successive parallel layers of chromite and pyroxenite by gravitative differentiation is so great that the theory of flowage has been generally accepted. Hence the widely prevalent steep dips of the chromite bands are not treated as indicating deformation of the dunite, even though they are looked upon as denoting a deformation of the settling layers of chromite by movements of the dunite magma.

Rock pressure is most commonly indicated by joints and step faults. Jointing is a striking feature in the region, especially about the central amphitheater. The joint surfaces in this region strike northwestward and dip 30°–40° NE., and at many places along the small streams a single such plane surface is laid bare for 1,000 square feet or more. The jointing will affect actual mining operations in several ways: it will aid greatly in the removal of rock, it will decrease the security of mine roofs where the joints are abundant, and it will permit the circulation of water to an extent which can be determined only by experience.

Faulting can be detected with certainty only where the bands of chromite have been displaced little enough to render obvious their original continuity. In small stringers four or five step faults will produce a total displacement of only a foot or less, but in stringers 2 to 6 feet thick a series of such steps may have throws ranging from 2 to 20 feet.

Examples of this sort of faulting are best exposed in the cliffs that form the outer walls of the dunite ridges. One such cliff stands at an altitude of 2,600 to 2,800 feet on the southeast declivity of the ridge running northeastward from Red Mountain, about a quarter of a mile from the dunite boundary. Here a 3-foot band of chromite shows an offset of about 20 feet just at the top of the talus slope, and four more bands that have an offset of equal or less amount are visible in a distance of 200 to 300 feet along the inaccessible wall above. Similar examples of faulting occur at an altitude of 2,400 feet on the spur extending southeastward from the high peak on the ridge running west-northwest from Red Mountain, at the same altitude on the southwestern side of the pyramidal peak between the two low passes to the Seldovia River drainage, and at an altitude of about 2,000 feet at the southerly head of Fish Creek. The same phenomenon is shown at the Star No. 4, Horseshoe, and Juneau No. 1 claims. In fact, this condition is so general wherever exposures are good that most of the abrupt ends of the chromite deposits are believed to be due to faults, even where the continuation of the "vein" can not be found or at least can not be positively identified.

Faults of greater magnitude are probably few, as the heavy bands of pyroxenite can be traced for long distances without perceptible dislocation. One major fault is thought to cut off a small northern segment of the dunite just south of the Juneau No. 4 claim, because the dip of the chromite bands here and farther northwest to the summit of the ridge is nearly vertical, and their strike is practically east and west, whereas the main part of the dunite area to the south shows very consistent north-northwest strikes and in most places dips of less than 50°. The alternative possibility may be mentioned that the part next to the contact is a portion of an early extrusion frozen to the rock wall and not moved by the subsequent outflow, which determined the attitude of the chromite and pyroxenite bands in the interior basin.

A more extended study of this fault or contact surface might lead to a satisfactory explanation of the abrupt change in position of the ore stringers which is so evident on the two sides of it.

In the main area the fault planes coincide with the most pronounced joint planes in position, striking north-northwest and dipping east at low angles.

This widespread faulting will obviously cause some inconvenience in the work of following the bands of chromite beneath the surface.

WEATHERING.

The rusty terra-cotta color that gave the name to Red Mountain, or Iron Mountain, as it is still sometimes called in locating mining claims, is due to surface weathering of the dunite. This outer oxidized layer in few places exceeds an eighth of an inch in thickness, but it is found nearly everywhere on the mountain, and as the summit is higher than that of most of the surrounding mountains and as vegetation is almost wholly absent it is conspicuous at great distances. The converse conclusion that rusty rock is an indication of dunite was found, as might be expected, to be entirely misleading, because many pyritized masses weather to a color that is indistinguishable from that of the olivine rock.

Rock disintegration is much more advanced in the contact zone than in the interior of the dunite area or in the surrounding rocks, so that wherever the contact crosses a ridge a saddle is formed. The only notable exception to this rule among seven such localities is on the ridge between the two heads of Fish Creek, where the saddle and the accompanying crushed and slickensided serpentinous rock are fully 2,000 feet inside the contact line. The cause of this exception was not worked out satisfactorily but is believed to be the presence of pyroxenic rock on the ridge, perhaps combined with an overthrust or an originally flat-lying contact. The pyroxenic phase of the igneous mass is clearly less readily hydrated than the dunite, and its product seems often to be chlorite rather than serpentine, which suggests questions as to the amount of alumina in the pyroxenite.

Disintegration by frost and glacial action has been much facilitated by the numerous systems of joints. In the main inner cirque, at an altitude of about 2,500 feet, blocks as long as 30 feet have been piled in promiscuous heaps. Where the glacial valley heads cross the dunite boundary there are usually terminal moraines of igneous blocks that quite obscure the contact.

PETROGRAPHY.

ROCK TYPES.

A study of thin sections shows that the rock masses which inclose the chromite are of three general lithologic varieties—dunite, pyroxenite, and serpentine. Intermediate forms are found and are especially abundant between dunite and serpentine, but the typical forms can be readily recognized even in the field. No exhaustive study has yet been made of these rocks, but a few of their features that are due to the geologic processes which have affected the region may be noted.

DUNITE.

Dunite is by far the most abundant type of the igneous mass. It ranges from very light gray or light rusty yellow through gray or green to dark gray or dark olive-green. All the varieties present a very uniform, smooth limonite-stained surface where they have been exposed to the weather. Much of the dunite, especially the darker rock, is traversed by a network of fine dark lines, which intersect at all angles or more rarely lie parallel. Under the microscope the massive light-colored varieties are seen to be composed mostly of granular olivine through which a small amount of chromite is disseminated. One specimen, No. 30, which contained the smallest amount of chromite observed, has a specific gravity of 3.277. The shattering of much of the olivine, the "strain shadows" generally seen under crossed nicols, and the elongated shape of the larger uncrushed remnants, some of which are ten times as long as they are wide, indicate the stresses to which these rocks have been subjected. The olive-green varieties that constitute most of the mass appear to owe their color to partial serpentinization, in some specimens very slight and in others nearly complete. The network of dark, fine veins that is almost universally seen in the olive-green dunite and the rarer parallel dark films seen in some of the lighter-colored varieties furnish evidence of the same shearing strains.

As seen under the microscope these veins appear to be composed of serpentine darkened by many small grains of ore, which is probably magnetite formed in the process of serpentinization, for the finely powdered substance of the veins is somewhat attracted by a magnet. The cracks in which this vein material is found were probably formed largely by the jar of volcanic explosions, for they have no general orientation and were produced before the serpentinization, which occurred early in the history of the dunite. The parallel dark films, which are similar in texture and mineral composition to the material filling the cracks, are looked upon as very thin layers crushed by regional pressure.

PYROXENITE.

In the field the pyroxenite was provisionally identified as websterite, on account of its microscopic resemblance to that rock as found at Hebbville, Md. It occurs in layers that range in thickness from a few inches to about 100 feet, and the larger masses are traceable for great distances, one band west of the head of Windy River being approximately a mile long. Three or four such bands are visible at each side of the Windy River valley just south of the northern limit of the igneous area, where the intercalated dunite is jointed into large blocks and the pyroxenite has almost the appearance of a heavy-bedded sandstone. The contact of the pyroxenite with the dunite is usually rather sharp, but at some places one grades almost imperceptibly into the other. The bands of pyroxenite are parallel to the stringers of chromite, so that the two probably had a common structural origin, but whether they were differentiated by gravitational separation or by magmatic flowage that stretched more equidimensional bodies into layers is not conclusively proved, though the latter explanation seems more probable. Typical pyroxenite was not observed at Claim Point, but small pyroxenic dikes or veins there cut the banded chromite, which may indicate that the pyroxenitic magma at Claim Point was much less abundant and perhaps less viscous than at Red Mountain. The hypothesis is here suggested that at Claim Point the pyroxenite magma may have been developed by the resorption of spinel ($MgAl_2O_4$) from the early formed chromite by the hotter (lower) dunite magma in the interstices of the chromite settlings. It would be intruded from these interstices rather than from a magma basin.

Under the microscope the pyroxenite is seen to consist almost wholly of grains of a monoclinic pyroxene 1 to 2 millimeters in diameter. Some of it shows the diallage parting. Yellowish or brownish areas that make up perhaps 3 per cent of the mass are doubtless composed of an alteration product from olivine or a rhombic pyroxene. The rounded grains of ore are not translucent but may nevertheless prove on further examination to be chromite. They are not so abundant as in the ordinary dunite, and the internal shattering is not so marked. It was observed only in the severely crushed outer zone.

The specific gravity of the pyroxenite was determined by the Joly balance to be 3.31, whereas that of the dunite was slightly below 3.28. This does not necessarily mean that the magma of the pyroxenite was heavier than that of the dunite. An experimental determination of this point would be instructive.

SERPENTINE.

Though the change of dunite to serpentine seems in its early stages to have imparted to the rock a greenish tinge, the distinctive color of the rock in which the alteration to serpentine is complete is a dull waxy-lustered chocolate-brown. Less commonly it is almost black. In some specimens from Claim Point and Red Mountain the microscope reveals no cores of olivine. These specimens show clearly and strikingly the netted structure that is characteristic of serpentine derived from olivine. The dark-gray and black serpentines seem, paradoxically, to owe their color to the fact that the iron in the original olivine of the rocks from which they were derived was all separated from the olivine as magnetite or possibly as magnoferrite in the process of alteration, so that no iron appears in the serpentines.

The change of dunite to serpentine appears to have taken place long ago. No indications of it appear along the more recent joint planes, or along the less recent fault planes, many of which have been recemented by hornblendic or feldspathic vein material. The most convincing evidence of the early origin of the serpentine is seen in an angular lens-shaped black mass measuring about 1 foot by 3 feet, which was found inclosed in the light-colored massive unaltered dunite at the water's edge just southeast of the Reef mine camp at Claim Point. This mass was at first thought to be a fragment of black slate, for it breaks up readily along lustrous black surfaces, but it proved to be a partly serpentinized dunite having a specific gravity of 3.13. The bright surfaces are due to slippage along cracks filled with serpentine and magnetite. Its occurrence seems to show conclusively that serpentinization antedated its inclusion in the dunite, as the dunite is neither cracked nor hydrated. It may be a part of the first solidification of the dunite, which was afterward shattered by explosions or pulsations and serpentinized along the resulting cracks by steam and then swept from its original location by movements of the magma.

The whole contact zone at Red Mountain may be a part of this early consolidation. The light-green alteration product that is abundant at the periphery of this area is believed to be chlorite derived from the pyroxenitic facies. This opinion as to the parent rock of the chlorite is based on the common occurrence in the chloritic material of fragments of pyroxenite which have smooth, slickensided surfaces and which are thoroughly crushed in the interior. If this opinion is correct the pyroxenite is aluminous, and interesting questions therefore arise as to its genetic relations to the nonaluminous dunite.

ORE DEPOSITS.

THE ORE BODIES.

The outstanding peculiarity of the chromite bodies of Kenai Peninsula is their continuity for considerable distances in bands or layers, for such bodies elsewhere are generally scattered and "pockety." This continuity 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 deposits may be cited in order to give definiteness to this statement. A deposit at the Reef mine, Claim Point, is about 135 feet long. At its east end this deposit is about 3 feet thick; a section near the middle measured 47 feet 5 inches, and another section farther west measured 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, which occurs in parallel banding with the chromite.

The longest ore body observed in the Red Mountain district is on the Star Chrome No. 4 claim. It extends for a distance of more than 600 feet as a deposit ranging in width from 6 to 11 feet, and it continues northward for at least 500 feet farther in the form of separate stringers, some of which are as much as 1 foot wide. Smaller stringers are numerous at many places where there is no workable ore. Some that were noted are a quarter of an inch thick and 2 feet long; others are 2 inches thick and 8 or 10 feet long. All show the same general layer-like shape.

THE ORE.

The chrome ores of the Port Chatham and Red Mountain districts vary greatly in appearance. Two pronounced types are chosen for description (see Pl. II), though intermediate forms are quite as abundant as these. One is the granular black massive rock, with lustrous surfaces where freshly broken, becoming dull brown through attrition of the fragments. The other is the banded variety, in which light and dark layers that lie parallel or nearly parallel present a striking contrast in color. The layers in the banded ore range in thickness from less than a twentieth of an inch to several inches, though on closer inspection the wider bands usually appear to show subsidiary banding with more indistinct boundaries between the light and the dark parts. The dark constituent is chromite; the lighter part is usually olivine, which doubtless contains a very small percentage of iron; or, much more rarely, it is 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 banded type in many places passes into the massive type through gradual increase in the quantity of chromite in the gray bands or through segregation of the two constituents, until the dark bands become massive chromite and the lighter material merges into the wall rock or forms a horse in the ore body. The lighter bands grade into normal dunite through decrease in chromite. The distinction between ore and rock is therefore not sharp, the banded ore running out, both along the strike of the bands and transverse to it, into dunite containing a few stringers of chromite. In the banded ores the chromite is at many places of sharp octahedral shape. In the massive ores well-formed crystals were not observed, possibly because internal motion of the mass or the same jarring forces that shattered the dunite may have rubbed away the sharp edges.

Certain mottled ores, seen only in small, loose pieces, appear to be banded ores in which the bands of olivine were very thin and have been stretched by pressure normal to their flat surfaces into a series of separate flakes.

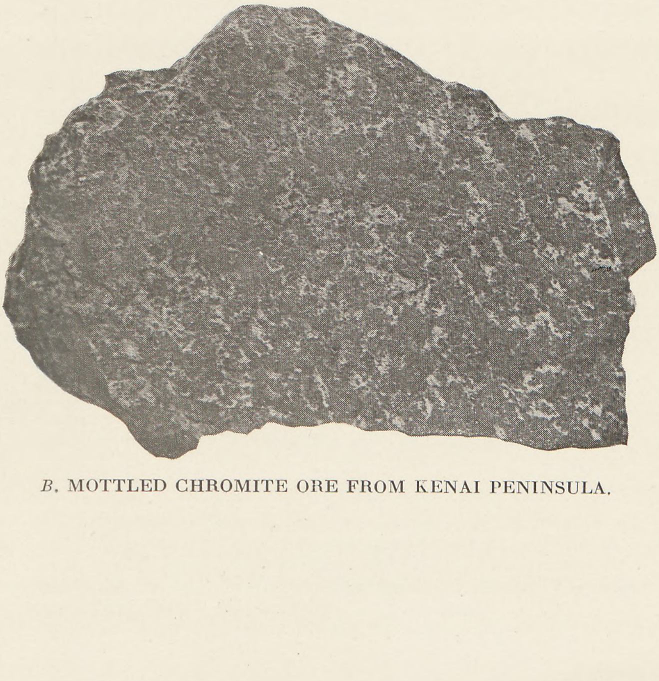
A less lustrous and more porous-looking ore, which was observed only in detached blocks near the saddle between the heads of Fish Creek, is regarded as of the massive type, perhaps dull and brownish because it is more finely powdered than the ordinary bright varieties.

Another variant of the massive ore is a chromite breccia that is found in several deposits, which are probably of no considerable economic value, at places across the bay north of Claim Point Hill. This breccia is composed of angular or subangular fragments, apparently cemented, in part at least, by the silicate magma, and it seems to be another result of the forces that have so extensively shattered the outer zone of the dunite.

MINERALOGY.

Most of the chrome ores of Kenai Peninsula are very simple in mineral composition. They are mixtures of chromite and olivine in varying proportions. Possibly some of the peripheral masses may contain serpentine or other products of weathering instead of olivine, but no special effort was made to determine this point, especially as no large ore bodies in the outer zone are well exposed. The pyroxenic dikes in the Claim Point ore are small, but their green color suggests that they contain chromium. The purplish-pink chrome chlorites were observed at several places, and a similarly colored harder mineral, which has not been studied, looks like a chrome chloritoid. Thin emerald-green films are not rare on the slickensided surfaces of the crushed chromite. They may be uvarovite or fuchsite. Finally, a peculiar hornblende, which occurs either with recrystallized chromite

A. BANDED CHROMITE ORE FROM KENAI PENINSULA.



B. MOTTLED CHROMITE ORE FROM KENAI PENINSULA.

or in bands that at a distance resemble in appearance and in position bands of chromite, may possibly be chromiferous.

It may be worth while to note both the practical and the theoretical desirability of making a more thorough study of the chemical nature and relations of the two principal minerals, chromite and olivine. Except the mineral chromitite,[7] which needs further investigation, the black isometric substance from which the largest percentage of chromic oxide (Cr_2O_3) can be obtained has been generally known as chromite, and its composition has been represented by a chemical formula or formulas of the type of spinel ($MgAl_2O_4$). It is customary to define chromite "theoretically" as $FeCr_2O_4$, with the explanatory statement that the iron is replaced to a greater or less extent by magnesium, and the chromium by an equivalent amount of aluminum or ferric oxide. This is a perfectly satisfactory treatment for the systematic mineralogist, who can add magnochromite ($MgCr_2O_4$) to his list and cover the complete known range of composition of chromite. If the constituent molecule $FeCr_2O_4$ usually occurred in practical purity or were usually predominent in the chrome ores there might be no serious objection to the present usage, but in the extensive unpublished list of analyses of chromite compiled by Miss E. F. Bliss (Mrs. Adolph Knopf) and kindly submitted to the writer for examination, as well as in the published lists of Wadsworth,[8] Cirkel,[9] Clarke,[10] and others, only one analysis, and that a very old and doubtful one, showed as much as 61 per cent of chromic oxide (Cr_2O_3), whereas chromite ($FeCr_2O_4$) should contain 68 per cent of chromic oxide (Cr_2O_3) and magnochromite ($MgCr_2O_4$) should contain 79 per cent.

Moreover, most of the analyses made show a higher percentage of MgO than of FeO, especially those of Turkish and Canadian ores. To what extent this higher content of magnesia may be due to the presence of olivine or serpentine can not be decided from the analyses and the facts at hand, especially from analyses containing no determination of silica.

The high content of magnesia renders intelligible the association of chromite with olivine and serpentine. If the term chromite may be used as a group name like olivine and chlorite, the term ferrochromite may be used for those rare combinations in which the molecule $FeCr_2O_4$ shows overwhelming predominance over its isomorphous associates.

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[7] Yovitchitch, Z., Soc. franç. minéralogie Bull., vol. 35, pp. 511–516, 1912.

[8] Wadsworth, M. E., Lithological studies, a description and classification of the rocks of the Cordilleras: Harvard Coll. Mus. Comp. Zoology Bull., vol. 11, pt. 1, 1884.

[9] Cirkel, Fritz, Report on the chrome iron-ore deposits in the eastern townships, Province of Quebec, Canada Dept. Mines, Mines Branch, Ottawa, 1909.

[10] Clarke, F. W., The data of geochemistry, 4th ed.: U. S. Geol. Survey Bull. 695, p. 703, 1920.

The practical value of gaining a more thorough knowledge of the minerals of the chromite group may be seen in the varying percentage of chromic oxide in these minerals, in the great significance of the associated constituents in deciding the uses to which the material may be put, and in the limitations imposed upon processes of concentration either by the chemical nature of the chromite in a particular locality or possibly by its specific gravity.

The answers found to theoretical questions as to the sort of magma from which the different varieties of chromite have separated out, the ratio of magnesium to iron in the chromite as compared with or affected by the ratio between these components in the accompanying olivine, the change in composition of chromite as crystallization progresses, and the part played by silica in the constitution of the mineral as suggested by the substitution of MgSi for Al_2 in the serpentine-chlorite and other groups may find practical application in the exploitation of chrome ores.

ORIGIN OF THE ORE.

The chromite ores of Kenai Peninsula, like those of many other localities, seem to have been almost wholly formed by early crystallization from a highly magnesian magma. Gravitational differentiation may have been more complete because of a considerable range of temperature and consequently a long time between the beginning of the solidification of the chromite and the beginning of the crystallization of the olivine. The massive ores are regarded as grains of chromite collected into more solid masses by settling, whereas the banded ores were similar granular masses, or at least masses of dunite enriched by chromite, which have been swept along by the currents of the possibly viscous magma. The sharp contacts between ore and rock are thought to be due to rapid flow of very liquid magma; the banded ores and contacts are accounted for by the interkneading of chromite in viscous dunite. By this interpretation the variable dip and strike of the bands of ore at the Reef mine, as well as at the large deposit on the northwest slope of Claim Point Hill, would indicate that the magmatic flow was disturbed by the heavy masses of chromite in its course. The fact that many bodies of chromite ore are "pockety" may be due to the breaking up of such continuous masses.

Though most of the chromite of Kenai Peninsula appears to be of magmatic origin the lustrous massive ore at the Babcock & Martin prospect, at the bluff end of Red Mountain ridge, seems to be an exception to the rule. The structural and mineralogic relations of this ore indicate that it was recrystallized. According to a determination of Chase Palmer in the chemical laboratory of the United States Geological Survey, it contains only 32.1 per cent of chromic oxide, although its specific gravity is 4.46. This recrystallized ore is very slightly magnetic. It would seem that recrystallization greatly modified the composition of the chromite and that complete chemical analyses might help to determine the typical composition of recrystallized chromite in general. This recrystallized material may, of course, have been derived from a part of the chromite deposit that originally had a composition different from that of the ordinary run of the exposed parts.

More detailed field and laboratory investigation would be required to clear up these uncertainties.

ORE BODIES AT PORT CHATHAM.

NUMBER.

What appear to be fourteen separate deposits that under normal conditions of the market might profitably yield more or less chromite were observed (see Pl. III), but this number may not represent that many distinct deposits. 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 were seen. Three of these show plainly that they are faulted parts of what was originally a continuous set of stringers, so that the eight or more separate masses may be dislocated parts of two stringer systems. These systems are about 30 feet apart and are 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 there is no definite evidence of their continuity, and in any event the connecting parts are probably not of workable quality.

A statement of the number of ore bodies is also made difficult by the lack of a definite limit showing the quality of the ore. The distinction between ore and chromiferous dunite must clearly be determined by wages, by methods of mining and concentrating, by conditions of transportation, and by the price of chromite. For present purposes it has been assumed that a content of 10 per cent of chromic oxide is sufficient to render concentration feasible under ordinary wages and prices. Estimates of quality were made in the field to be checked later by analyses and determinations of specific gravity in the laboratory. An example of the accuracy of this method may be cited. Specimen 26 from Claim Point was estimated to contain 15 per cent of chromic oxide on the assumption that one-fourth of its volume consisted of chromite. Its specific gravity, which was found to be 3.58, appeared to confirm the field estimate, for calculation from what seemed to be the most probable indications of value—that is, 4.4 as the specific gravity of the chromite, 55 per cent as its content of chromic oxide, and 3.28 as the specific gravity of the olivine (determined on the purest of the neighboring olivine rock)—would give 17 per cent of chromic oxide. In the chemical laboratory of the United States Geological Survey Chase Palmer found 28.62 per cent of chromic oxide in a sample taken from this specimen. This discrepancy may indicate to a certain extent imperfect sampling of the specimen, but it is more probably due to a lower specific gravity and higher content of chromic oxide in the chromite than had been assumed. If these were placed at 4.1 and 65 per cent, respectively, the calculation from a specific gravity of 3.58 would give 27.3 per cent of chromic oxide.

This explanation has been introduced here in order to make plain the uncertainty as to the exact number of ore bodies visited. Low-grade stringers that were not regarded as workable may be the "tailing out" of richer deposits, or they may be more chromiferous than the estimates made would indicate. It is believed that no bodies have been mentioned which contain less than 10 per cent of chromic oxide in the ore exposed.

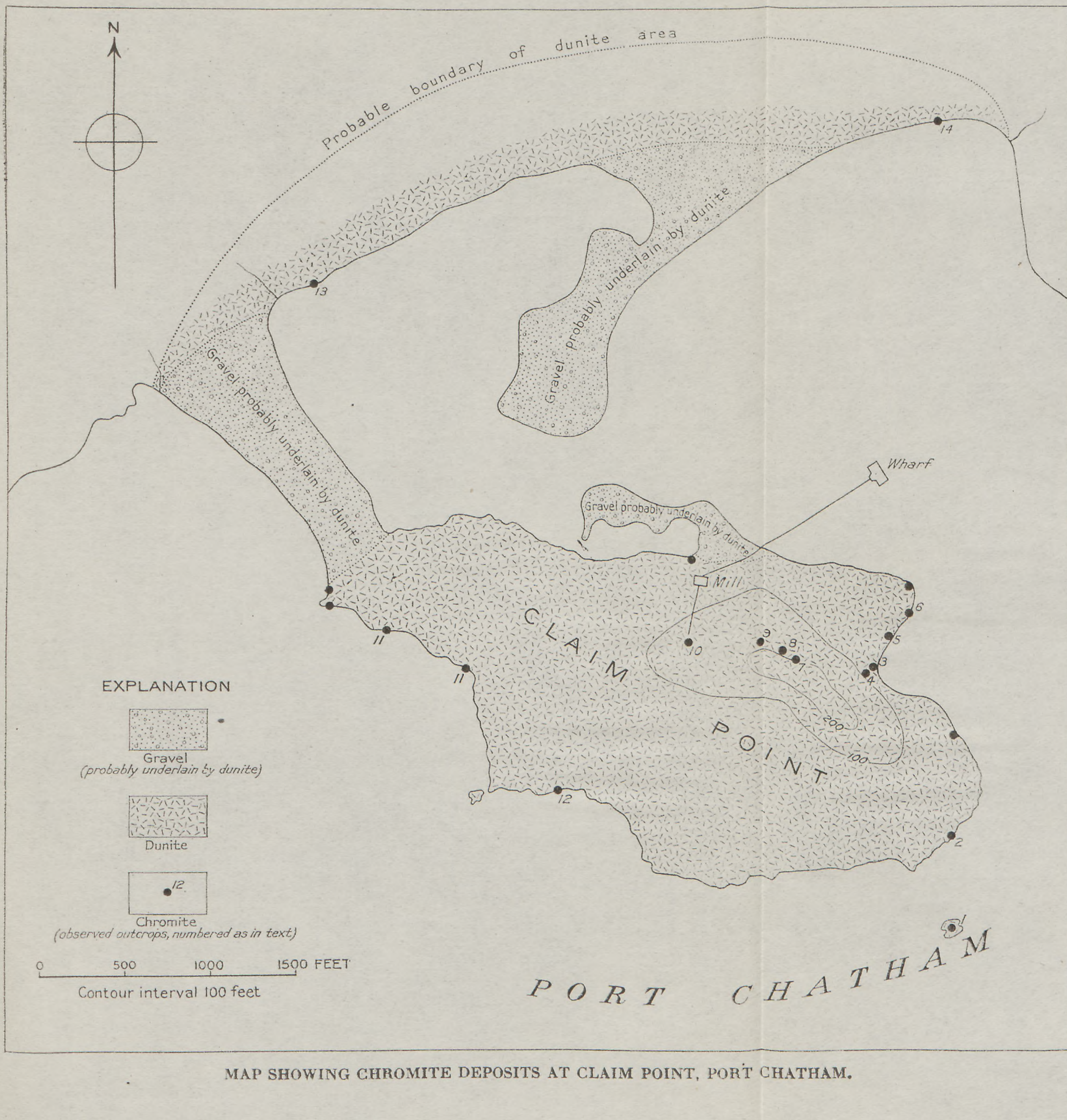
Details as to the number of mining claims located in the Port Chatham area were not obtained. It is reported, however, that Whitney & Lass, who now control the properties originally staked by Philip ("Scotty") McCray, have filed new claims covering the remainder of the chromite at Claim Point.

POSITION.

All the known workable ore bodies at Port Chatham except one were either laid bare by wave action at the shore line or were exposed in the naked rock on the upper north slope of Claim Point Hill. The exceptional one is the very large mass on the northwest hillside to which the tramway leads. This occurs in a wooded region, and its magnitude was shown only by partial stripping. There is no reason to suppose that the parts of the dunite area covered by forest and other vegetation or the parts under water are devoid of chromite, but exploration has thus far uncovered only this one mass in the forested area.

DIMENSIONS AND CHARACTER OF THE INDIVIDUAL ORE BODIES.

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 characteris-



MAP SHOWING CHROMITE DEPOSITS AT CLAIM POINT, PORT CHATHAM.

tics of these ore bodies may perhaps best be shown by describing in some detail each body that seems capable of furnishing marketable ore, even though the quantity may not be large. The numbers assigned to the deposits correspond to those used on the map (Pl. III) to indicate their location.

Deposit No. 1.—On a small island that lies southeast of Claim Point Hill and 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 is nearly vertical, though the component ore bands show much local variation in dip and strike. Its length is about 135 feet, and its width ranges from 3 to perhaps 35 feet. A section across the main heading at high-tide level was measured on July 9, 1918, as follows:

Section at main heading, Reef mine.

	Ft.	in.
Dark ore, 40 per cent	6	
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	
Massive black ore	2	2
Waste	2	6
Half and half	1	
Waste	1	1
Half chromite in wedge-shaped bands	5	5
Massive ore, good to medium quality	11	1
Mostly waste	6	3
Shipping ore	1	
Waste	2	6
Good ore, 40 per cent	1	5
Scattered stringers, no sharply defined wall.		
	47	5

Faulting has doubtless increased the apparent thickness along this line probably 10 feet or more.

Section 50 feet southwest of main heading, Reef mine.

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

The highest point on the good ore between these two measured sections is about 18 feet above mean low tide. Some poor ore southeast of the main lode lies 5 to 10 feet higher. The depth below water level, on the assumption that it is half the horizontal length, would be 65 to 70 feet. The impression of the mine operators that this mass of ore becomes 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. It was hoped to show this divergence in a photograph, but all the photographs taken failed to show a contrast of color between the black chromite and the associated silicate rock, perhaps, as is suggested by Prof. O. D. von Engeln, of Cornell University, because of the relatively strong reflection of the blue or even ultra-violet "actinic" light by the chromite. It is estimated that the part of the ore below tide at the Reef mine is greater than that above, even without assuming that the ore body increases in thickness at the lower levels, as the height above the water line is so small a fraction of its length.

The content of chromic oxide in this ore in the output of 1917 reached 46 to 49 per cent. In the season of 1918 the operators found it advantageous to ship ore that contained approximately 40 per cent of chromic oxide, 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 did not maintain the percentage of chromic oxide reached in 1917. During both years a certain amount of low-grade ore was broken and not used, which will be available for concentration when the mill is in operation.

Deposit No. 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 is nearly vertical. A smaller mass to the east may well be, as Mertie has suggested, a faulted part of the same deposit, but it seems not to be of workable size.

Deposits Nos. 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 that were probably originally parallel and about 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 appear to contain at least 30 per cent of chromic oxide. At the base of the cliffs at a distance of less than 50 yards in both directions from the main exposure there are many stringers of chromite of very low grade. Their original continuity with the higher masses is extremely hypothetical, yet as the shattered country rock suggests faulting, and as the vertical component of the throw here, as at the Reef mine, is probably much greater than the horizontal component, the change in the character of the deposit is not greater than might be expected.

Deposit No. 5.—About 75 yards northeast of the high wall just mentioned a set of very irregular lenses and stringers of chromite is exposed for a height of 25 feet just above the beach. At the bottom there are small stringers, but in the middle there is some shipping ore, though even in this part of the deposit 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 a brownish serpentine, which appears to be thoroughly weathered, on account of its proximity to the fault zone to which water had free access.

Deposit No. 6.—Fifty yards east of deposit No. 5, below high-tide level, a sharply bounded lens of massive chromite is 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 deposit last mentioned. 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 continues for some distance under water, indicating a greater extent for the deposit than that 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 has 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 chromic oxide. A white mineral in the cracks of this ore appears to be aragonite.

Deposit No. 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, which is about 30 feet long, shows 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 is 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 in part a greenish monoclinic pyroxene, in places occurring as dikes, one-third of an inch thick, cutting diagonally across the bands of ore, and in part a light-colored olivine that weathers rusty yellow.

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 stringers of chromite, which may be a continuation of the same deposit, faulted and displaced toward the south from the part that is 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.

Deposit No. 8.—In another test pit, 40 feet northwest of deposit 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 of which had a specific gravity of 3.62 to 3.7, averaging 3.66. On each side of this ore occurs poorer ore 2 to 3 feet in thickness. 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 part 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 most of the ore is similar in quality to that just noted, though in the southeastern 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 much more than that indicated by the two excavations—that is, 140 feet—because 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 average width of the ore bands for the distance exposed by the two pits may be taken at 18 feet, as it is 11 feet in one and 25 feet in the other.

Deposit No. 9.—On the hillside 60 feet about N. 20° W. from the westerly opening on deposit No. 8, is a lens of rich chromite 4 inches wide and 4 or 5 feet long. It is accompanied by many smaller stringers of chromite on both sides. This lens may not be a part of a workable deposit, but it is interesting because it is the site of a small fault that displaces the ore about 6 inches, indicating the presence of fractures in this region. Stringers seem to be scattered over a considerable width here, as a few small ore bands are exposed in an opening 60 feet farther down the hillside in a direction N. 20° W. This opening was made with the intention of cross-cutting by a tunnel to deposit No. 8. The strike of all these bands is about N. 70° E., and the dip is nearly vertical.

Deposit No. 10.—What seems to be the largest deposit of chromite at Claim Point—if, indeed, it is not part of an originally continuous mass some 1,200 feet or more long connecting deposits 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 deposit 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 can now be said as to the original continuity of these deposits than that many small faults have been observed in the region, all with displacement such as to indicate continuity if the faults had the proper amount of throw, 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. The tramway starts from it, and the 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 to obtain information for this report it had not been sufficiently developed to afford a clear idea of its size. 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 chromic oxide (?)	5	5
35 per cent chromic oxide	4	7
5 per cent chromic oxide (too rocky to work?)	2	2
35 per cent chromic oxide	5	5
50 per cent chromic oxide		8
35 per cent chromic oxide	10	
Covered by soil and vegetation	18	
50 per cent chromic oxide	1	6
	47	9

In this cross section the ore estimated at 35 per cent of 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. If the specific gravity of the silicate constituent is assumed to be 3.28—the specific gravity of the purest of the silicate rock, which, however, contained a little chromite—and if the specific gravity of the chromite is assumed to be 4.4, the ore tested would contain 63 per cent of chromite. If the specific gravity of either the silicate mineral or the chromite is actually lower than has been assumed, the percentage of chromite must be greater than the amounts calculated. The specific gravity of either may differ from that assumed because, (1) as above noted, the silicate material on which the determination of specific gravity was made contained some chromite and the silicate part of the ore appears somewhat dull, as if partly hydrated, and (2) the blackest pieces of 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 ore estimated to contain 15 per cent of chromic oxide has already been discussed (see pp. 17–18) with reference to the high percentage of chromic oxide shown by analysis, 28.62 per cent.

The bands in this ore body are more irregular in course than those in most others. They range in strike from N. 34° E. to N. 59° E., though most of them strike about N. 54° E. The dip is nearly vertical but in some places is northwest.

In order to determine approximately the length of the deposit a workman furnished by Whitney & Lass made several small pits along a line run southwestward about 100 feet across the ore body. Four of these pits 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 line run across the ore body some 75 feet farther southwest he dug two pits, 8 feet apart, to bedrock. Both showed ore that appeared to be like specimen 26, the field estimate of which 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 a decreasing content of chromite along the strike or is simply, as is so frequently observed elsewhere, a leaner band interbedded with better ore. Chromite was found 25 feet northeast of the main exposure, though only slightly exposed. The total length of the ore body is thus at least 200 feet, probably more, and the width may be placed tentatively at 30 feet.

Deposit No. 11.—Along the rocky shore where the low-lying west end of Claim Point Hill faces the open ocean there are many stringers of chromite in more or less detached exposures for an extreme distance of 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, about 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 but includes 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 the length of the workable parts can not be determined. Doubtless considerable ore could be mined above low tide, and very likely a larger quantity at greater depth.

Deposit No. 12.—About 600 feet along the shore southeast of the east end of the series of deposits last mentioned, there is a set of bands of chromite striking N. 52° E. and dipping almost vertically. The chromiferous zone appears to be about 30 feet wide, though its boundaries are rather indefinite. Single layers of clean chromite reach a thickness of about an inch. Some of these layers 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. Another exposure of similar ore about half as wide occurs 50 feet to the east. It is perhaps a part of the same bands, offset, as usual, to the right.

Deposit No. 13.—On the beach at the base of the cliffs northeast of Claim Point Hill there is a considerable amount of chromiferous sand, which has been much concentrated by wave action, though it still contains a large percentage of what appears to be olivine. Whether this material is rich enough for direct shipment or should be further concentrated had not been determined at last reports, though if a mill were in operation near by its shipment would perhaps be found profitable. The sand has evidently been derived from the friable rock by wave action. Its quantity is small compared with the deposits that occur in place, yet it and other similar deposits that may be found hereafter are worthy of consideration.

Deposit No. 14.—A deposit of chromite of no considerable economic importance lies 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 about 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, and others are filled with original silicate material or with what looks like a talcose alteration product. The open spaces may have been caused by removal of the carbonated or otherwise altered silicate constituent.

These deposits may indicate that large continuous bodies of chromite are not likely to be found in the brecciated outer zone of the dunite and that nearly all the originally large bodies have been broken into detached masses.

RELATION OF THE ORE BODIES TO THE DUNITE.

The boundaries between ore and country rock are at some places sharply defined, as, for example, at deposit No. 6 (p. 21), but far more commonly the transition from the larger ore masses to dunite is gradual, brought about by the increasing distance between the stringers of chromite or by decreasing content of chromite, as in the less markedly banded ores. These gradual transitions are extremely variable. At some places 4 or 5 feet of chromiferous rock at the contact may be all below workable grade, as at deposit No. 11, whereas at places in the Reef mine (deposit No. 1) there is a gradual transition from very black ore to practically pure olivine within 4 inches. The significance of these relations in determining possibilities of cobbing and concentration is readily appreciable.

STRUCTURAL RELATIONS.

Some of the structural features of the ore bodies are susceptible of simple and certain explanation; others present complex problems. The bands of ore on opposite sides of many of the smaller faults were obviously once continuous, and the fault planes usually show slipping. But the larger faults and the phenomena of dip and strike are less simple. Practically all strikes are oriented between northeast and east, and dips are mostly steep—from 70° to 90°. Whether the fluctuations are due to curvature of the bands of ore, to original discontinuity, or to faulting is all-important in the work of following the ore and estimating its quantity. Though the ore bodies at some places seem to show curvature, the great abundance of small faults and angular jointed blocks with slickensided surfaces suggests that they have been most commonly deformed by a series of step faults with displacement to the right. Larger faults are indicated by crushed zones. Some of the fissures that cross the banded ores are filled with pyroxenic material. These filled fissures appear to be dikes rather than veins, but they are nowhere abundant enough to modify essentially the character of the ore.

PHYSIOGRAPHIC RELATIONS.

The surface features of the chromite bodies seem to indicate that either pure chromite or pure dunite is more resistant to subaerial weathering than a mixture of the two, the difference being possibly due to difference in coefficient of expansion by heat. One curious effect of this difference is to make the lean mixtures of chromite and olivine appear to be poorer than they really are, because frost and rain have loosened and removed the grains of chromite, leaving a surface of almost pure olivine. Several specimens show sharp triangular depressions where the octahedral crystals of chromite have been removed. The high-grade ores, by the same sort of disintegration, seem to lose grains of olivine and appear to be richer than they really are. But the abrasive action of ice-moved or water-rolled rock fragments appears to be always greater on the chromite than on the country rock. Hence it is well worth while for a prospector to investigate elongated depressions such as mark the locations of deposits Nos. 6, 7, and 8.

COMPOSITION.

No thorough study has been made of the nature of the chromite constituent of the Port Chatham ores nor of the minerals that form their impurities. For the season of 1917 Lass[11] 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, as 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 the purpose of checking field estimates and of 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 chromic oxide.
Deposit No. 6, specific gravity 4.4	46.84
Deposit No. 1 (Reef mine), specific gravity 3.79	34.67
Deposit No. 10, specific gravity 3.58	28.62

The field estimates of these specimens were 50, 35, and 15 per cent of chromic oxide, respectively. The discrepancy in the specimen from deposit No. 10 has been discussed on pages 17–18.

The need for complete analyses and careful determination of the nature of associated minerals will doubtless be more strongly felt when concentration is in commercial operation. Enough evidence has accumulated to show that olivine and its alteration products are by no means the only impurities, although they are the principal ones in the banded and lower-grade ores.

The market requirements have not yet placed any limit on the quantity of alumina (Al_2O_3) that the ore may contain, but the silica has been restricted to a maximum of 8 per cent.

As intimated above, the marketing of the concentrates may introduce new methods of determining the value of the ore from its composition, mineral and chemical.

[11] Lass, W. P., Chrome deposits of Alaska: Min. and Sci. Press, vol. 117, p. 653, 1917.

QUANTITY OF MINABLE ORE.

The quantity of ore that is minable is computed on the assumptions 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 that shown by the exposures, either on account of faulting or covering by débris, or both, it is difficult to make safe estimates as to depth. Assumptions as to continuity have already been discussed. (See pp. 20–26.) 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 from 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 the basis of calculation. The estimated percentages of chromite check reasonably well with determinations of specific gravity, though it should perhaps be stated that the six chemical analyses that were made give an unexpectedly high content in chromic oxide for the lean ores and a lower content than was expected 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 (pp. 19–25):

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.

At Port Chatham the ore has been mined by open-cut workings, chiefly at the Reef mine. A large part of the output has been taken from the area that lies between the marks of high and low water, and great inconvenience has been experienced from the tides. Any considerable additional production from this deposit will necessitate an entire change of method, for a large part of the ore that lay above low water has been removed. It is therefore probable that the next deposit to be exploited will be No. 10. (See pp. 23–24.) At this deposit relatively light stripping will uncover a large body of ore on the hillside in favorable position for removal. A large quantity may be mined by open cuts, which 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.

The operations on deposits Nos. 2, 5, 7, 8, 9, 10, 13, and 14 have been mainly exploratory, though a little ore has been shipped from several of them.

SHIPMENT.

The facilities for shipping the ore from Port Chatham were much improved during the season of 1918. A new wharf was constructed in the bay north of Claim Point Hill, and with the cooperation of the United States Coast and Geodetic Survey a wire drag of the harbor was carried out.

Notwithstanding these efforts the operators of the chromite mines say that they have been unable to get transportation for their output, so that it was impossible for them to complete the delivery of 1,000 tons of 40 per cent ore for which they had a contract at $1.50 a unit. About 200 tons was loaded on a barge July 17 and towed to Seldovia, where it was left standing at the dock on July 29 by the steamer that was expected to take it. Latest advices are to the effect that little more than 600 tons was shipped prior to December 31, 1918, when the contract was canceled. On January 4, 1919, 300 tons of 42 per cent ore was shipped to Seattle, but the market conditions were such that it could not be sold at any price. How far the uncertainties of Alaskan transportation were a result of war conditions during the season of 1918 and how far they are an index of general shipping conditions in that region the experience of the writer does not enable him to judge. It is clear, however, that the chromite mines can not be successfully operated unless these matters are taken into account.

ORE BODIES AT RED MOUNTAIN.

NUMBER.

In the Red Mountain area not less than 23 deposits capable of furnishing chrome ore under favorable conditions of transportation were observed in place. (See Pl. IV.) In addition to these at least 10 occurrences of good ore in loose blocks were noted. Some of these blocks indicate heavy deposits; others may have been derived from bodies too small or too crushed to be workable. Perhaps some of the abundant and rich-looking fragments of chromite east of the main head of Windy River have been brought by glaciers from the great mass to the southeast, on which the Star Chrome No. 4 claim is located, but most of them are probably derived from ore bodies not seen in place, or, if they were derived from any of those seen, they are so located as to indicate an immensely greater extension of those bodies than was assumed in the estimates of quantity.

The number of mining claims actually located in this district, as nearly as could be ascertained, is 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.

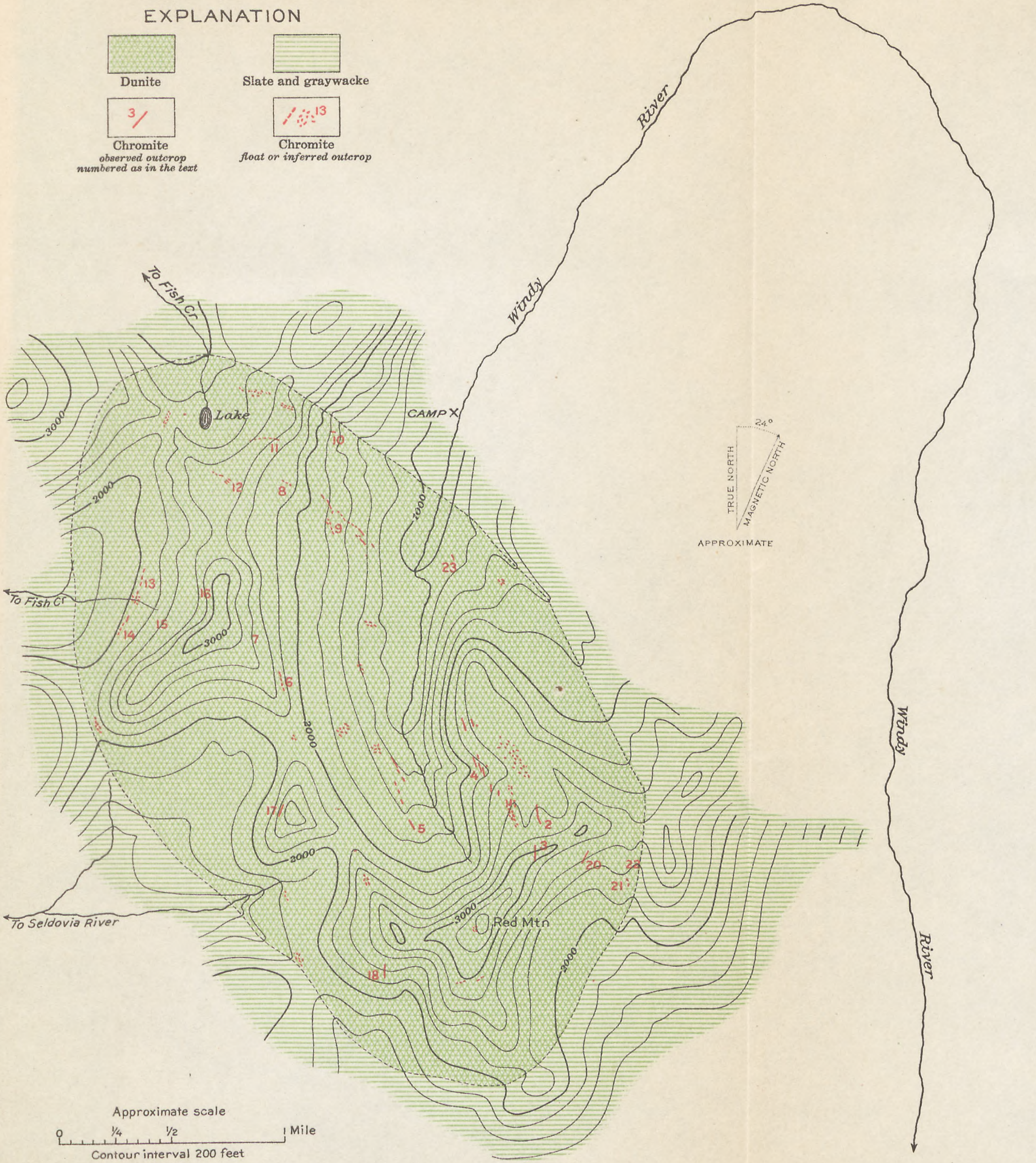
POSITION.

The ore bodies seen in place at Red Mountain occur in the firm jointed dunite and not in the crushed and hydrated outer zone. The single exception is deposit No. 22, which is in that zone. Most of the larger masses of ore seen therefore lie on the inner or outer walls of the horseshoe ridge. The fact that they were found at somewhat higher altitudes may be due rather to the concealment of ore by the débris that covers the lower slopes than to a less abundant supply of chromite in the rocks there. If any part of the area is really devoid of workable chromite it would seem to be the southeast slope and cliffs of the spur between the drainage basins of Fish Creek and the northern fork of Seldovia River.

DIMENSIONS AND CHARACTER OF THE INDIVIDUAL ORE BODIES.

The ore bodies in the Red Mountain district on the whole seem to be longer and thinner than those at Port Chatham and less markedly banded but nevertheless strikingly similar in character. The deposits will be described in order of location on a line running first around the inner basin at the head of Windy River and then around the outer slopes of the main ridge. (See Pl. IV.)

Deposit No. 1.—At the northwest end of the high ridge that divides the main amphitheater at the head of Windy River from the valley of its small tributary, which runs along the dunite contact parallel



MAP SHOWING CHROMITE DEPOSITS AT RED MOUNTAIN, KENAI PENINSULA, ALASKA

By A. C. Gill

1922

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

to this ridge and north of it, there is a chromite deposit on one of the Babcock & Martin claims. Its altitude is about 2,300 feet, and the descent from it to Windy River, to the northwest, is precipitous. This deposit is unique in that it is composed of two parts that appear to be of different origin. The larger 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 usual strike of 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 of the chromite stringers at this locality. A sample of the ore has a specific gravity of 4.46 and contains only 32.10 per cent of chromic oxide. (See p. 42.) This ore was noted in the field as probably recrystallized, and its variation in composition from that of the usual type was assumed.

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, considering the low tenor of the recrystallized ore, it is probably of minor importance, as its thickness decreases to about 1 foot within 40 or 50 feet.

Deposit No. 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 claim known as Star Chrome No. 4, located by F. A. Rapp for Whitney & Lass, and is at an altitude of about 2,600 feet on a sort of ridge-ribbed plateau in the east 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:

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
Total thickness (2 feet 11 inches is waste)	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 in the less resistant chromite. In spite of the abundant loose material, the exposures are numerous enough 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
Total thickness (3 feet 6 inches is waste)	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 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 an offset of 10 feet to the right shows 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 gravities 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 be conservatively placed at half the volume of the ore body.

Deposit No. 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, there 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, 18 inches of which seemed to be of shipping grade and the remainder was rated at 20 per cent of chromic oxide.

Deposit No. 4.—West of north from deposit No. 3, at many points on the rough surface of the westward-tilting "plateau," there are stringers of both high and low grade chromite, most of which seem too small for separate mention, 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-inch 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 at altitudes of about 2,000 to 2,200 feet along the south wall of the stream that drains this so-called plateau area. It is probably continuous for the whole distance along the wall, though it was actually 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, which, of course, obscured the view of the ore, if, as is thought probable, it was exposed. This layer is somewhat more than a foot thick. 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 of chromic oxide.

Deposit No. 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 foot 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, there 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, is about 2 feet thick and is much contorted. This deposit, 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 this deposit 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 variable.

Deposit No. 6.—The rich but small ore lenses that occur near the two low divides to the Seldovia River basin lie nearly horizontal. 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 that seems to be connected by low-grade stringers with the main mass. The ore here lies nearly horizontal.

Deposit No. 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 40 per cent ore with 1 foot of rocky material on each side of it, which was judged to carry only 5 to 10 per cent of chromic oxide. Uphill the width decreases to only 6 inches of good ore within a distance of 10 feet. If it widens 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.

Deposit No. 8.—On the shelf or narrow plateau, which is seemingly a remnant of the old valley floor not removed by the glacier that deepened the center, at an altitude of a little more than 2,200 feet, 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 of material that grades regularly from rock to shipping ore, 82 inches of good ore, and 12 inches of material that shows gradation back to wall rock. About 100 feet southeast of this point a pit dug through 3 feet of surface material uncovered 5 feet of banded and disseminated ore, half of which is estimated to contain 30 per cent of chromic oxide and the rest to be 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. About 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 an abrupt end, 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.

Deposit No. 9.—The series of chromite layers described together under No. 9 would probably have been classed as at least three separate deposits, or very likely more than that, if time had been available for carefully working out all details observable in the exposures, which appear in the irregular cliffs southeast of deposit No. 8, at altitudes of 1,200 to 1,800 feet. None of them showed 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, where they pass to inaccessible cliffs in which they can be seen for perhaps 100 yards farther. They appear to pass under the Juneau No. 1 lode and are separated from it by a heavy band of pyroxenite, which, like many smaller ones observed in this locality, is parallel to the ore. 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 bands of high-grade chromite, approximately in parallel position under those just mentioned. The largest of these bands 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.

Deposit No. 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 1 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, and 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 fragments of chromite for 100 feet or more. These fragments 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.

Deposit No. 11.—A quarter of a mile south of the lowest pass between Windy River and Fish Creek a heavy band of chromite apparently crosses the main ridge, which is here double for a considerable distance, the two parallel crests being 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 1 foot with a cross section, beginning at the north, showing 30 inches nearly half of which is chromite, 48 inches consisting mostly of rock, and 84 inches of good ore, at least two-thirds of which is of shipping grade. A hundred feet eastward down the mountain side 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 the section revealed 72 inches of ore, at least half of it estimated to run 40 per cent or better in chromic oxide. This deposit may have been originally a part of No. 9, but the intervening area is accessible with difficulty, even where it is not covered with talus.

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 thick can be seen in the vertical rock wall with a dip of about 45° S.

Deposit No. 12.—From deposit No. 11 the main dunite ridge runs due southwest for 500 or 600 yards to a culminating point that 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 seem to have a thickness of 2½, 5, and 2 feet, respectively. The largest 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.

Deposit Nos. 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° E., and dip east at a variable angle, mostly much less than 45°. No. 13 is north of the main stream and can be followed along the mountain side for fully 500 feet. It is broken at many points by small faults. Its thickness ranges from 1 to 2½ feet of fair concentrating ore, with only a little that appears to carry as much as 40 per cent of chromic oxide. Toward the north end there are three bands of chromite, each more than a foot thick, in a section of 100 feet, and one of them is probably the continuation of this layer, though the continuity is established only by the occurrence of chromite of similar rather low grade in the blocks fallen from the cliffs. Still farther north, 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 material that is nearly of 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. Deposit No. 14 can be followed for more than 400 feet, from the main stream approximately along the top of the talus slope toward the divide between Fish Creek and a branch of Seldovia River. Its thickness is nowhere less than 1 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, which at one point is 1 foot thick. The dip of the ore becomes flatter toward the south.

Deposit No. 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, there is a band of chromite from 12 to 24 inches thick, which is estimated to carry 35 per cent of chromic oxide. Toward the southwest it is cut off by a fault. About 50 yards distant and 30 feet higher than this faulted end there are some low to medium grade stringers that are judged to be the continuation of the same ore body. Toward the northeast it passes under the talus with a thickness of 2 feet and with seemingly increasing magnitude. The main exposure is 50 or 60 feet in length.

Deposit No. 16.—High in the wall of the cirque, about northeast of deposit No. 15, occurs 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 supported by the increasing dips of the chromite bands in that direction. The presence of a heavy band of pyroxenite below the deposit 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 layer of pyroxenite.

Deposit No. 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 body of chromite of considerable size. 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 probably extension to that slope. On the northwest declivity, however, at an altitude of about 2,400 feet, just above the talus slope, it shows for a distance of 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, and then it gradually frays out into a series of separate lenses to the south. Several small faults, the largest having a displacement of about 6 feet, show relative uplift 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.

Deposit No. 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 body of chromite ore that 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 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 indicates that the ore body continues down the spur with good quality and in considerable size.

Deposit No. 19.—On the spur that runs nearly south from the summit of Red Mountain, at an altitude of about 3,000 feet, there is considerable low-grade chromite débris, 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 stated that it was the largest body of chromite ore he had seen at Red Mountain, the next largest being deposit No. 3. (See p. 32.)

Deposit No. 20.—At an altitude 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 dunite contact) between the upper and lower parts of the Windy River valley, lies a body of banded chromite. Its thickness is 3 feet where it passes beneath the talus, and it maintains 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 more than half chromite. A sample taken to show its average quality was found to have a specific gravity ranging from 3.73 to 3.87.

Deposit No. 21.—On the ridge that runs S. 16° W. from the pass just mentioned, at an altitude of a little more than 2,300 feet, there are three small deposits of chromite, covered by a mining claim of F. P. Skeen. The largest of these deposits shows a thickness of 2 feet of ore that runs about 30 per cent of chromic oxide for a distance of 8 feet. The smaller deposits, just above this one, are of better grade but are only about 1 foot thick. All three are apparently terminated by faults.

Deposit No. 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 that 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 it is so much crushed that it can not be profitably compared with the ordinary ores. The character and distribution of loose material suggest that the ore continues for perhaps 100 feet downstream from its lowest outcrop.

Deposit No. 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 there 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 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, there are three 1-foot stringers of low-grade chromite that strike N. 22° W. and dip about 60° 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 value.

DEPOSITS INDICATED BY FLOAT.

Streams, glaciers, and frost have moved loose fragments of rock so widely that it is doubtful whether an acre of fragmental rock in the Red Mountain dunite area could be found that did not bear visible stringers of chromite. Yet at many places unusual accumulations leave no doubt that a body of workable chromite ore is near at hand. There are also places where fragments of rich ore occur in such a manner as to show that the ore extends for a considerable distance, though there is no evidence that its thickness is sufficient to render it workable. Some of the most promising of these occurrences are 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 fragments of chromite, most of them less than 3 inches long. They extend for at least 200 feet. The best of the ore is mottled and has the composition shown in analysis No. 6 (p. 42).

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

On the ridge between the two heads of Fish Creek, about 150 yards west of its lowest point, much brownish porous-looking chromite (analysis No. 5, p. 42) occurs 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 100 yards S. 25° E. from the low pass, there are many small fragments of ore, which indicate 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.

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 blocks may have come from deposit No. 16, seen in the cirque higher up, but they are so abundant as to suggest a much nearer source, for it would seem that they would 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 200 feet, there are many rich-looking fragments of chromite, some as much as 6 inches in diameter. They extend some distance downward along the contact on the side toward Seldovia River, but if present on the slope to Fish Creek are covered by a large snowbank and talus from above. Similar fragments 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 that slopes northwestward to Windy River, there are very abundant fragments of chromite 2 or 3 inches in length estimated to contain from 30 to 45 per cent of chromic oxide. These fragments doubtless mark a considerable ore body.

Only three localities at which chromite float occurs in the inner basin of the Red Mountain ridge will be mentioned, though less extensive deposits of float were seen at many places. At two of these three localities the float was probably derived from ore bodies in place that have already been described. They are both on the rough-surfaced plateau on which deposits Nos. 1 and 2 were found. At one of them the chromite consists of widely scattered high-grade blocks each weighing from a few pounds to half a ton, 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 locality is at the southwest edge of the plateau along its southerly half, and the float consists of immense blocks of dunite, in which occur many stringers of banded chromite. One block 25 feet or more in length, perhaps from deposit No. 3, was cut by a 3-foot layer of concentrating ore estimated to contain 20 per cent of 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 1 foot of fair shipping ore.

RELATIONS TO THE DUNITE.

The chromite at Red Mountain shows the same relations to the dunite as were observed at Port Chatham. On the whole, very black ore with sharp contact against the country rock seems more common at Red Mountain.

STRUCTURAL RELATIONS.

One marked feature of the bands of chromite at Red Mountain is their parallelism with the layers of pyroxenite. This parallelism was observed at many places and characterizes the 2-inch stringers of pyroxenite as well as the heavy bands. The importance of this fact was recognized very early, but the necessity of visiting so many exposures of chromite and the uncertainty as to whether successive bands of pyroxenite were faulted parts of the same mass or were separate units led to the postponement of a special study of the pyroxenite as a means of recognizing layers in which chromite occurs until it was too late to work out this study satisfactorily. There are doubtless three or four heavy layers of pyroxenite which would by careful study aid in locating major faults, if present, and would help in finding the faulted prolongations of ore bodies whose position with reference to pyroxenite may be known.

Both the pyroxenite and the chromite layers are nearly horizontal in the region of the Seldovia Pyramid, and the dips become steeper toward the north, east, and west, whereas toward the south and southeast only nearly horizontal ore bands were seen. The bands dip eastward under the west limb of the main ridge, southward near the north end, and southwestward or westward in the interior basin and the region to the southeast. The general attitude of the ore bands resembles a syncline with a north-northwest axis pitching steeply southward at the north end and flattening out toward the south. The folding appears to have resulted in repeated step faults instead of bending without rupture.

PHYSIOGRAPHIC RELATIONS.

In general, the bodies of chromite have had little influence on the topography, hardly showing a notch where they cross a ridge, but in deposit No. 2, where the outcrop is roughly horizontal, glacial erosion seems to have excavated a trench 500 feet long. The accumulation of snow in this trench caused careful prospectors to overlook the most extensive ore body in the region less than two weeks before its discovery. When it was found most of it was still covered with snow, but two weeks later it was entirely exposed.

COMPOSITION.

The quality of the Red Mountain chromite has not been thoroughly studied, though the specimens collected include much material that is available for study. 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 chromic oxide in the aberrant varieties, as the great similarity to the Port Chatham material, combined with the high percentage reported by Grant [12] (57 per cent chromic oxide) 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.	Chromic oxide (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 content of chromic oxide, 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 a somewhat spongy texture is no indication of inferior ore. The porosity may be due to the removal of some of the interstitial silicate. The impurity in the specimen of porous mottled ore and in the other specimen of porous ore seems to be olivine.

A large number of samples were collected, and it has not been possible to make a careful study of their silicate constituent within the time available, but many facts indicate that such a study would be of great interest and practical value, especially if made in conjunction with similar studies of specimens of ore from other regions.

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[12] 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. 238, 1915.

QUANTITY OF MINABLE ORE.

The estimates of the quantity of chromite in the ore of the Red Mountain deposits were made in the same way as those for the ore at Port Chatham. (See p. 28.) This method of estimation assigns a very large quantity of ore to the deposit on Star No. 4 claim, a quantity so much larger than that assigned to any other claim in the region that some doubt is felt about its accuracy. However, the excellent exposure of this deposit at the surface leaves no doubt as to its length, so that it would be quite as reasonable to infer that the length of the other deposits has been underestimated on account of poor exposure or of faulting as to assume that the depth of the Star No. 4 ore body has been overestimated because it is longer at the surface. On the whole, the alternative that the estimates are low seems more probable, though the uncertainty as to depth should never be forgotten in considering the significance of the figures. The following table brings together the detailed estimates for the larger deposits. It includes only masses that appear to contain more than 500 tons, because this quantity is within the limit of probable error of the larger numbers.

Estimated quantity of chromite ore, in tons, in certain deposits at Red Mountain as calculated from the observed dimensions.

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

On the assumption, as before, that two-thirds of the chromite in the concentrating ores can be recovered, 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 was not decided upon in 1918 by the holders of chromite claims, though Whitney & Lass devoted a good deal of time during that summer to searching for a feasible route for the transportation of loose or readily accessible ore.

CONCLUSIONS.

AMOUNT OF ORE.

On the assumption that material containing 10 per cent of chromic oxide can be profitably concentrated the quantity of ore above sea level at Port Chatham has been placed at 32,300 tons. There may be a much greater quantity below sea level, as the lower deposits are generally richer and heavier than the higher ones, a fact which is in accord with the theory that the ore was formed by settling in a molten magma. But even by the same process that was used to determine the quantity of ore above sea level, an estimate of the ore in the exposures examined gives a total of 12,600 tons below sea level. 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 quantity of chromite in sight at Red Mountain is placed at 195,600 tons. This quantity is a minimum, 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 area of the dunite is covered by loose rock.

One notable feature of these deposits that makes all estimates of quantity uncertain is their tendency to divide along the strike into parallel bands and thus to grade 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 chromite bodies of Kenai Peninsula promises to make a deviation from the open-pit method of working both feasible and ultimately necessary. Cross-cutting at levels much below the outcrop may save hoisting of the ore and may reduce the distance from the mouth of the mine to the shipping point. One obstacle to underground mining will doubtless be the occurrence of numerous faults, though some localities have undergone much less faulting than others. In planning mining it should be borne in mind that in places where the strike of the faults nearly coincides with that of the ore bodies, as it does near the Star No. 4 prospect at Red Mountain, the ore bodies may be much less continuous at depths than at the surface, though extension in depth is to be expected when the continuation is located.

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

CONCENTRATING.

So long as chromite containing 40 or 45 per cent of chromic oxide is marketable, it will doubtless pay to continue the present hand sorting except at the few deposits where the ore is 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 that are composed chiefly of low-grade ore which would not repay the cost of exploitation if only shipping ore were marketed. Much of this material, say that running above 10 per cent of chromic oxide, can doubtless be profitably concentrated by washing. Concentration has proved 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 was being installed in 1918, after preliminary tests made in one of the mills operating on gold ore near Juneau. This milling project has been undertaken at Claim Point, though it will be necessary to pump water or to bring it 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 chromite in this region would require concentration, and if ore carrying less than 10 per cent of chromic oxide can be profitably milled the quantity of available chromite will be much greater than that indicated by these estimates, though, of course, the percentage suitable for direct shipment would be less than that suggested.

Experiments made to determine the relative behavior of olivine, pyroxene, and serpentine under mill tests would be of much practical interest. Experience has shown that the economical handling of these ores would require the installation of concentrating machinery.

The spongy and friable ores can doubtless be readily crushed, though the slimes may prove troublesome, especially in the shattered ore.

The recrystallized chromite and, possibly, some of the original mineral can not be brought by concentration to a high content of chromic oxide, as even the purest chrome-bearing mineral 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, and an extension of this tramway system may be found satisfactory for the higher deposits on the north side of the hill, though the alternative procedure of tunneling from a point near tide level and entering the high sea wall at the northeast bight is suggested by the possibility that the stringers of chromite 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. Concerted planning by all the holders of chromite properties in the region would probably 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 an outlet. Practical miners who have studied the situation seem to agree that the aerial tramway 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 different routes may be compared.

Tutka Bay has deep 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 stretch of Windy River for 2½ miles, then over a low divide, estimated to stand at an altitude of about 800 or 850 feet, into a canyon-walled head of Jakolof Creek. Whether the right wall of this canyon would be as difficult to pass as the left is not known, but as seen from below it appears to be easier. The route of approach to Tutka Bay from the low flat land is also 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 about the same distance from the dunite area as Tutka Bay. The upper part of the route from both to the deposit would be identical except as facility in the lower course might indicate a different location higher up. But Jakolof Bay is more rocky and shallow, a fact that might necessitate a longer road to navigable water.

Fish Creek, which enters 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. The valley of this stream as seen from above looks passable for a road beyond the first steep descent over glacial débris. 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 an altitude of less than 2,200 feet.

Seldovia Bay has the advantages of a well-charted harbor and a populated town. The route from Seldovia Bay to Red Mountain would reach dunite at an altitude 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 lie along a very steep, rocky mountain side. Its upper end would pass over alternating flats of glacial boulders and rather steep rock or talus slopes.

Rocky Bay appears to be excluded from consideration because its harbor is extremely dangerous and because Port Dick is equally accessible from the landward side and incomparably safer by water.

Port Dick has deep water to a point within a mile of the head of the bay. The configuration of the bay is such that the tidal currents are moderate for this region. The valley of Port Dick Creek leads to that of Windy River over a flat divide, estimated to rise 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. The grades by way of the Windy River valley around to the inner basin would also be moderate, 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 altitude of approximately 2,000 feet around the outer slopes of the dunite might connect all the peripheral ores with either Barabara Point, Seldovia, or Port Dick, and 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 several lower bands of chromite. The northerly head of Fish Creek would seem most promising for a tunnel if this method were to be considered.

Investigations by Whitney & Lass into the possibility of an inexpensive wagon road for emergency shipment from the inner part 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 that enter Jakolof Bay with low divides to the Windy River basin.

SHIPMENT AND MARKETS.

Ocean freight rates will doubtless be a permanent factor in the production of chromite in Alaska, as the lack of a local market is likely to continue indefinitely. If these rates remain as in 1918—$3.50 a ton to Seattle—it seems probable that the expense of delivering ore from Cook Inlet at points on the Pacific coast need not be greater than that for ore from many of the deposits in California and Oregon. It is impossible to forecast the level of wages in foreign countries, but if chromite from New Caledonia, South Africa, Australia, and other countries can be sent to Atlantic seaboard points at less cost than from Alaska, there still remain the interior and western markets, to which access will be had on practically equal terms with California and Oregon. It is even conceivable that the production of coal in Alaska may lead to the establishment of metallurgic plants near the mines.

But such hypothetical conditions may be disregarded in view of the fact that in 1917 and 1918 Alaska chromite was placed on the market by way of Seattle at prices that encouraged the producers to invest considerable sums in preparation for more extensive operations.

POSSIBLE OCCURRENCE OF OTHER VALUABLE MINERALS.

PLATINUM.

In the search for areas of peridotite other than those already known the sands and gravels brought down by many streams whose mouths lie between Port Dick and Tutka Bay were examined. Some samples were taken without concentration; others were washed in a pan used for washing gold. No platinum was found, and as all sands that seemed to hold out any special prospect of containing platinum were carefully washed, it is very doubtful whether platinum is associated with the dunite at Port Chatham or Red Mountain, at least in the eroded parts of the deposits.

It was reported in 1918 that a sample of beach sand from the neighborhood of Anchor Point, Cook Inlet, had been found to contain platinum, but this report has not been verified.

NICKEL.

In the hope that they might contain nickel several specimens of what appeared to be pyrrhotite were collected near the hut at the head of Port Dick and from the brecciated rock associated with the diorite at Koyuktolik Bay and at Point Bede. Samples of these specimens were submitted to R. M. Overbeck, of the Geological Survey, for such study as his wider experience with Alaskan nickel minerals might show was worth while. So far as field observations indicated, the rock of both the areas of chromite-bearing dunite appears to be free from sulphides or arsenides, though the "acid dikes" of the region at many places contain pyrite.

INDEX.

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