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CHROMITE DEPOSITS IN THE
SOURDOUGH AREA, CURRY COUNTY
AND THE BRIGGS CREEK AREA
JOSEPHINE COUNTY, OREGON

BY

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CHROMITE DEPOSITS IN THE SOURDOUGH AREA, CURRY COUNTY, AND THE BRIGGS CREEK AREA, JOSEPHINE COUNTY, OREGON

By F. G. Wells, L. R. Page, and H. L. James

ABSTRACT

The Sourdough, or Baldface, area is on Baldface Creek, in secs. 35 and 36, T. 40 S., R. 11 W., Curry County, Oreg., 31 miles west of U. S. Highway 199. The chromite occurs in a large body of peridotite near its contact with slates, sandstones, and pyroclastic rocks, which are probably Jurassic. The peridotite is partly saxonite, partly dunite, and is largely serpentinitized. It is cut by diorite dikes of both northeasterly and northwesterly strike. The peridotite is also cut by two fissure systems, of which one strikes N. 50° W. and has an average dip of 50° NE. and the other strikes about N. 20° E. and dips 60° SE.

Chromite crystals are disseminated through most of the dunite and locally the crystals are aggregated in streaks or layers separated by barren layers. Some layers or lenses of massive chromite range from a few inches to several feet in thickness. Where undisturbed, they strike about northwest and dip about 45° NE.

The chromite that might possibly be mined is all in one zone, which has been shown by prospecting to be at least 2,400 feet long and 965 feet deep. The rapid changes in the tenor of the rock makes any estimate of tonnage without systematic sampling and exploration a guess, but the district may contain between 50,000 and 100,000 tons of milling ore.

The Briggs Creek chromite deposits are on Chrome Ridge, in secs. 11, 14, and 23, T. 36 S., R. 9 W., Josephine County, Oreg. There was considerable activity in this area during the World War.

The known deposits are all in the southern part of a sill-like peridotite mass, which has been intruded into a group of hornblende schists or gneisses and thin-bedded quartzites that may be regionally metamorphosed equivalents of the Jurassic (?) rocks in the Sourdough area.

At least 95 percent of the peridotite in the Briggs Creek area is saxonite. The remainder is dunite, which occurs as small clots scattered through the saxonite. The chromite occurs in the dunite. The peridotite has been sheared and displaced along faults that trend N. 20°-45° W.

The ore is mainly of the disseminated type, with some fairly high grade streaks, but some consists of pods and masses of chromite along fissures in dunite. No significant trend of the ore bodies has been recognized. The dunitic layers, which contain the disseminated chromite, seem originally to have ex-

tended northward but to have been offset by strong northwest-southeast shearing. The chromic-oxide content of the chromite ranges from about 39 to 55 percent. The deposits are so numerous and widely scattered as to give a misleading impression of their value and size. The high-grade lenses contain considerable ore, but the horizontal and vertical extensions of individual ore masses are small.

No large tonnage has been developed of ore assaying as much as 10 to 20 percent of Cr_2O_3 , which grade would be required to warrant concentration on a large scale under present conditions.

INTRODUCTION

Chromite occurs at many places in the Klamath Mountains of southwestern Oregon and northwestern California. In most districts in this region the chromite that is likely to prove worth mining is mainly massive ore in pods, "kidneys," and lenses, most of which contain less than 50 tons, though a few pods are known to contain 1,000 tons or more. In some districts, however, such large masses of rich ore are lacking and the chromite is mainly disseminated, though it also forms nodules and layers, in more or less altered intrusive rocks that originally consisted mainly of olivine. Even though such rocks may contain less than 20 percent of chromite, in sufficient tonnage they might produce commercial quantities of ore that could be concentrated to yield 45 to 50 percent of chromic oxide. Two such deposits, the Sourdough, or Baldface, and the Briggs Creek, or Sordy, were studied in the fall of 1939 by a field party in charge of F. G. Wells and including L. R. Page, H. L. James, Robert Yates, W. M. Furnish, and Martin Koenig.

Only a small part of the Klamath Mountains has been geologically mapped, but the rocks of the region are known to consist in general of highly folded and faulted sedimentary and volcanic rocks, most of which have been metamorphosed, and younger intrusive rocks. The oldest rocks are crystalline schists. Paleozoic argillites, quartzites, and marbles, interlayered with metavolcanics, crop out over large areas, and Jurassic (?) sandstones and slates are present. The intrusive rocks range

from granite to peridotite. All the chromite deposits are in peridotite.

SOURDOUGH, OR BALDFACE, AREA

Geography

The Sourdough chromite deposits, as they are now usually called, were described by Allen ^{1/} as the Baldface deposits. They are in a rugged unsettled mountainous area in the southwestern corner of the Kerby quadrangle, just north of the California line, in Curry County, Oreg. This area is 31 miles west of O'Brien, which is on U. S. Highway 199 (see fig. 68). It is on a spur of the Wimer Road which, like the spur itself, is a dirt road with steep grades and is impassable in wet weather. Most of the exposed chromite is on the north side of Baldface Creek, in secs. 35 and 36, T. 40 S., R. 11 W. Baldface Creek flows in a narrow valley, intrenched about 1,700 feet below the neighboring crests. The steepness of the valley walls has resulted in extensive landsliding just north of the claims. Baldface Creek, as well as the North Fork of Smith River, which it joins a mile downstream from the deposit, has a large flow.

Geology

The chromite of the Sourdough area is concentrated in thin layers of dunite, many of which are enclosed in a mass of serpentized and sheared saxonite. These ultrabasic rocks form the margin of a large heterogeneous body intrusive into tuffaceous sandstones, shales, and pyroclastic breccias of Jurassic (?) age. They in turn are cut by diorite dikes and have been faulted and serpentized apparently after the injection of the dikes.

^{1/} Allen, J. E., Chromite deposits in Oregon: Oregon Dept. Geology and Min. Ind. Bull. 9, pp. 34-35, 1938.

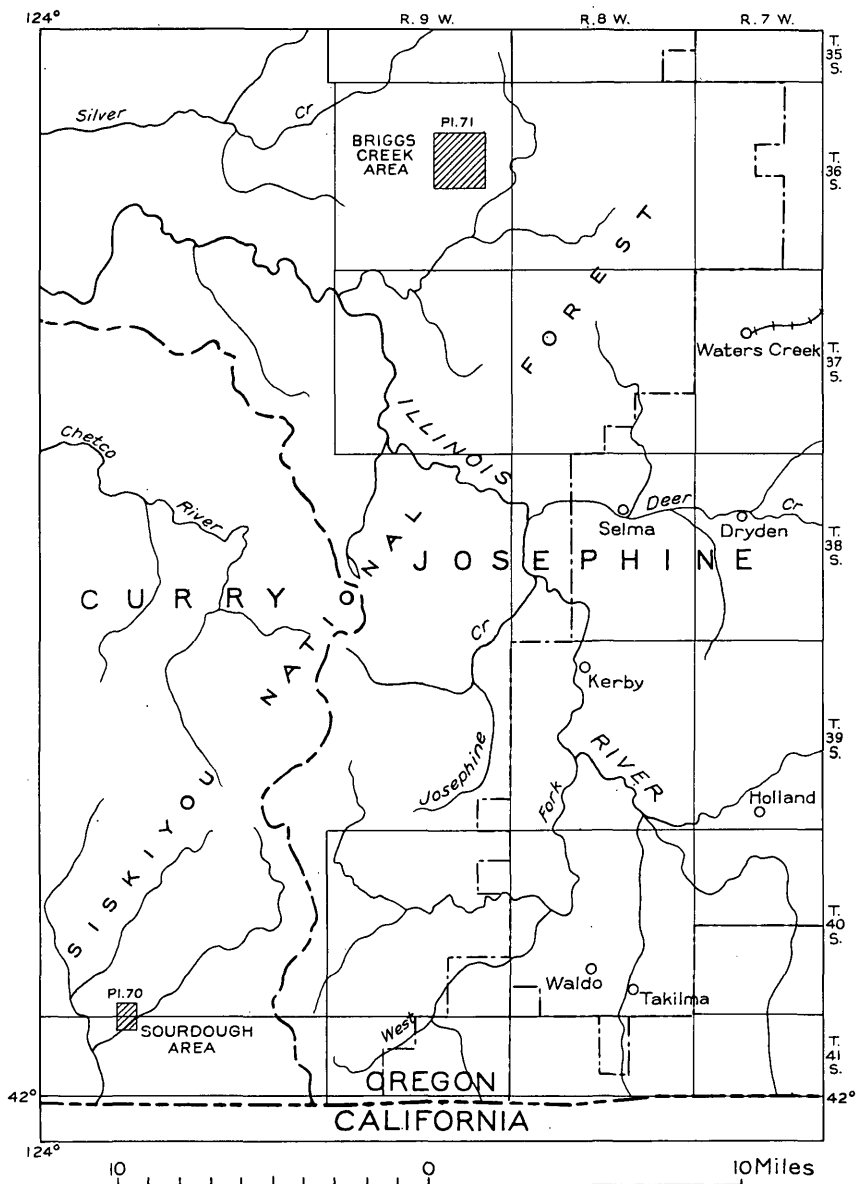


Figure 68.--Index map of southwestern Oregon showing location of Sourdough and Briggs Creek areas.

The chromite is in part disseminated and in part forms massive streaks and lenses in both fresh and altered dunite, of which it is an original constituent. Shearing along the contacts between massive chromite and dunite, which is visible in most of the pits and exposures, indicates either that the chromite has been concentrated along shear zones or that the shearing has been localized by chromite layers. The ore zone has not been sufficiently explored to determine its limits or even its trend. Its ore, on the whole, is of low grade.

Jurassic (?) sedimentary rocks

The supposedly Jurassic rocks, which crop out in the western part of the area mapped (see pl. 70) are unresistant, poorly exposed, and much overgrown with brush, except along their contacts with the intrusive rocks, where metamorphism has made them more resistant. Only near these contacts have they been attentively studied. The rocks exposed at the contact are in part dense, hard light-gray to greenish fine-grained hornfelses. In part they are breccias which, in a matrix of similar hornfels, contain fragments of recrystallized, medium-grained rocks that are apparently dioritic. In places the fragments are slightly serpentized or otherwise altered. Banding is visible here and there in the breccias, but it is so indistinct that its precise attitude was observed only at the northwest corner of the Come and Get It claim, where it strikes N. 40° W. and dips 85° NE.

The dense hornfels shows no bedding and little of its original texture, but its association with the breccia, which looks like a pyroclastic rock, and its gradation into fine-grained tuffaceous beds in the unmetamorphosed parts of the formation suggest that it also is pyroclastic in origin.

The width of the zone of intense metamorphism averages about 25 feet and reaches a maximum of at least 100 feet. Beyond this zone is one in which the Jurassic (?) rocks are mica schists or phyllites, which grade westward into white, gray, greenish and greenish-brown feldspar-rich shales and tuffaceous sandstones. The schistose rocks are exposed where the contact is crossed by the road and by Baldface Creek, and also in an inlier on the southeast side of this creek. Along the road feldspar-quartz schist is interbedded with chlorite-mica schist, in which a poorly developed foliation parallels the bedding. These rocks might well be derived from tuffaceous sandstones and shales.

Dark-gray to black phyllitic schists, interbedded with thin layers of brownish, green-weathering, limy chert, crop out where Baldface Creek crosses the contact. They are separated from the serpentine by 10 feet of hornfels. Float of unaltered tuffaceous sandstone and shale observed within 25 feet of slightly serpentinized saxonite, about 700 feet south of this point, suggests that the foliation in these schists may be the result of shearing.

The inlier southeast of the creek is composed of gray quartz-mica schist. The moderately well developed but rather widely spaced planes of foliation may be a false cleavage due to shearing, for the nearest dunite and saxonite have a similar structure; however, it is difficult thus to explain the variation in dip from vertical to 10° SE. in such a small area. The absence of visible contacts makes it impossible to determine whether this inlier is a thin veneer of schist faulted onto the igneous rocks or an actual inclusion or roof pendant.

Intrusive rocks

Saxonite.--Saxonite, a rock composed of olivine and enstatite, is the predominant rock of the area. It shows all stages of alteration to serpentine. The freshest, in the southeast part of the area, is greenish black and medium- to coarse-grained. Enstatite crystals or pseudomorphs after them, the largest of which are about three-eighths of an inch long, are conspicuous on the weathered surface, where they are white to gray and contrast with the matrix, which is brownish when weathered. Nearly all of the saxonite has been serpentized to some degree. Where serpentization has been rather intense the weathered surface is light gray and the altered pyroxene crystals are dark.

The saxonite grades, by decrease in the proportion of pyroxene, into dunite, and field relations indicate that the two rocks were differentiated from a single magma. The rock in the southeast half of the Black Cub No. 1 claim is predominantly of an intermediate facies, which might be called dunitic saxonite. It has the texture of saxonite but assumes on weathering the yellow-brown or buckskin color that is characteristic of dunite. Thin layers and small irregular masses of true dunite are common in this facies.

Very small grains of chromite occur throughout the olivine of the typical saxonite and are more abundant in the dunitic saxonite.

Dunite.--The dunite masses, in which the chromite is concentrated, are almost wholly enclosed in saxonite. The dunite where fresh is a fine-grained dark greenish-black rock; its weathered surfaces are smooth and of yellow-brown or buckskin color. It has been serpentized, like the saxonite, and where the alteration is complete is usually gray on the weathered surface.

The layers or irregular masses of dunite that occur in the saxonite have gradational boundaries. They range in thickness from 2 inches to 55 feet, but poor exposures make it impossible to determine their length. The thickest layer may be traced through the line of test pits, but its apparent trend is probably a resultant of steplike offsetting by many cross faults, although only one of these faults was definitely observed, and that one offsets a diorite dike in the northern part of the Old Diggings claim.

Another layer at least 20 feet thick is fairly well exposed on the east side of Baldface Creek, 100 feet east of the boundary of the intrusive mass. It is probably continuous with a layer striking N. 20° W. and dipping 25° NE. that is exposed for a distance of 350 feet between the 1,300- and 1,500-foot contours. A little disseminated chromite was noted in the exposures, and float of high-grade chromite occurs in the dry gulch to the northeast.

Many thin layers of dunite (designated by d's on the map, pl. 70) crop out in the Old Diggings and Come and Get It claims. These layers are poorly exposed and have an average thickness of only about 5 feet.

Inasmuch as serpentinization decreases the difference in appearance between the dunite and the saxonite, it is not everywhere possible to trace the boundaries of sheared and serpentinized dunite, and some serpentine derived from dunite has doubtless been mapped as saxonite. Serpentine rich in chromite is likely to have been derived from dunite.

Serpentine rock.--Throughout large areas the ultrabasic rocks are so completely altered that no trace of their original texture has been preserved. Marked alteration has taken place mainly along the contact with the Jurassic (?) rocks, and it reaches its extreme along zones of intense shearing that strike

about N. 60° W. and N. 20° E. Where the shear-zones cross it, the intrusive contact is sharply jagged and probably faulted. The serpentine rock here is thoroughly shattered and slickensided, but both the alteration and the shearing decrease in intensity to the northeast, where the rock, though completely serpentized, is more or less massive and shows some traces of its original texture. This facies grades into rock showing little serpentization except along the walls of fractures. Such rock is cut by cross-fibered grains of chrysotile. Highly fractured and completely altered zones a few feet wide are common along the eastern boundaries of the chromite ore bodies.

Diorite dikes.--Gray, medium-grained, more or less altered diorite is seen in many places to cut the saxonite. Individual areas of such rock are less than 100 feet wide but evidently much longer, and although it has been impossible to trace any one of them very far they obviously represent dikes.

Terrace gravel

Coarse gravel consisting of large pebbles, cobbles, and boulders is found on the east side of the canyon of Baldface Creek as high as 400 feet above the stream, and a patch of similar material lies on the west side. The gravel is of unknown thickness. It consists mainly of ultrabasic rocks and contains fragments of massive chromite.

Structure

As only a small part of the ultrabasic body was mapped, its structural relation to the older rocks is uncertain. Judging, however, from the strike of the Jurassic (?) rocks along the contact, the body is rudely conformable and sill-like. The streaky distribution of the chromite, assuming it to be a primary structure, supports this assumption. The layers rich in

chromite, where undisturbed, strike northwestward and dip about 45° NE.

Two main systems of shearing are recognized in the area, and many minor trends are recognizable. Roughly speaking, the dominant system strikes N. 50° W. and dips 50° NE., and the other main system strikes N. 20° E. and dips 60° SE. A dike and the main intrusive contact have been displaced by faults of northwesterly strike.

Chromite deposits

Most of the dunite contains disseminated chromite--chromite, that is, in rather evenly scattered separate crystals--but in the richer rock the crystals are mainly concentrated in streaks or layers, which are separated by barren layers. Layers of massive chromite from a few inches to several feet in width occur in places; elsewhere the chromite is not so highly concentrated. The layers dip, as said before, about 45° NE.

The following analyses were kindly furnished by the Rustless Mining Corporation.

Partial analyses of chromite from the Sourdough area

	1	6	9
Cr ₂ O ₃	53.62	48.96	54.33
Fe ₂ O ₃	15.85	14.34	13.42
SiO ₂	3.52	5.84	3.51
	72.99	69.14	71.26

1. Homogeneous, black, well-crystallized friable ore.

6. Dense, black, hard ore.

9. Same as 1.

The silica reported indicates that the chromite was not completely separated from the silicate gangue minerals before analysis. The ratio of metallic chromium to metallic iron in all three samples is more than 3 to 1.

A sample of disseminated ore from the Sourdough area that contained 18.75 percent of Cr_2O_3 was concentrated. Recovery was 74.5 percent of the contained chromite, and the concentrate assayed 52.97 percent of Cr_2O_3 .

Exploratory pits, trenches, and adits have been confined largely to the Old Diggings and Come and Get It claims, although small pits have been opened on all except the Owl claim. These workings show fair indications of chromite over a horizontal distance of about 2,400 feet and a vertical distance of 965 feet. If slighter showings are included, the horizontal distance would be increased by about 750 feet and the vertical distance by about 150 feet.

All statements in the following pages regarding grade of ore are based on visual estimates only.

Old Diggings claim

Chromite is exposed in most of the workings of the Old Diggings claim. Two large pits, a caved adit, and five smaller pits and trenches have been dug in the southeastern half of this claim, and two small pits, showing small amounts of chromite, in the northwestern half.

The best exposure of the ore body is in the large pit about 100 feet north of the middle of the southeastern end of the claim. The pit, which is badly caved, is 125 feet long and averages about 25 feet in width, although it is 45 feet wide in the widest place. Banded and disseminated chromite is well exposed for 20 feet across the banding and 10 feet vertically. The ore body, in the places where it is apparently undisturbed, strikes N. 45° W. and dips 45° NE., but it is cut by many fractures and has been rather strongly contorted. On the eastern edge of the ore body a strong shear zone strikes N. 60° W. and dips 35° NE., bringing saxonite in contact with dunite and ore.

It was estimated that over the entire width of the exposed surface chromite makes up from 35 to 40 percent of the ore and that at least half of this occurs in high-grade lenses or streaks from 6 to 8 inches thick.

On the dumps and ore piles there is at present about 25 or 30 tons of 35-percent chromite ore, and about 500 tons of similar ore is exposed in the pit. Stripping along the strike of the ore body and diamond drilling might well prove a considerably larger potential deposit.

The caved adit on the lower part of the sledge road is apparently on the same ore zone. High-grade ore occurs on the eastern edge of the dunite band, which is 55 feet wide. The exposures here are poor, but judging from the ore on the dump this adit was driven in a high-grade zone. The ore exposed is in lenticular masses that dip 45° NE., nearly parallel to the main shear zones, which strike N. 45° - 55° W. and dip 45° NE. On the western edge of the dunite band there is a pronounced shear zone with about the same strike and a dip of 35° NE.

Three small pits north and west of the caved adit are badly caved but show banded and disseminated ore similar to that noted in the big pit described above. The banding strikes N. 55° W. and dips 40° NE. Although no high-grade ore was noted in place here, the ore pile shows about 20 tons of high-grade chromite ore in pieces so large as to indicate that they came from layers or lenses as much as 12 inches thick. The location of these pits with respect to the caved adit and big pit, as well as the apparent sudden termination of the diorite dike to the east, probably indicates that the ore body is offset slightly to the southwest at this point.

The largest pit on the Old Diggings claim is in the center of the claim, at the end of the sledge road. The pit is 175 feet long and, though very irregular in shape, averages about

30 feet in width and 10 feet in depth. The ore is dunite, faulted against saxonite along the northeastern edge of the pit, in a shear zone that strikes N. 20° W. and dips 30° NE. One exposure of chromite 4 feet long and 1 foot wide shows very high grade ore. About 50 tons of similar ore is piled up near the pit. Small exposures of banded ore show a strike of N. 40° W. and a dip of 30° NE. Very little ore was exposed in 1939, and it is impossible to give an accurate estimate of the reserves indicated by this pit.

Come and Get It claim

The workings on the Come and Get It claim consist of three groups of pits and an adit, concentrated at the ends and the middle of the claim. The adit, which is on the road at the northwest end of the claim, was 40 feet long when visited. It was being driven northwestward in dunite, along the dunite-saxonite boundary, to intersect the ore exposed in the pit 40 feet uphill from the portal of the adit. About a ton of high-grade ore is exposed near the entrance of the adit, but only widely scattered specks of chromite were observed in the last 20 feet. The ore in the surface pits is of low grade and contains about 35 percent of chromite, which is partly in layers and partly disseminated in dunite. The layers strike N. 45° W. and dip 30° NE., which is approximately the trend of the shear surface along which the adit was started. A well-developed shear plane in the adit 36 feet from the portal strikes N. 60° W. and dips 43° NE. It cuts the dunite and is relatively free from serpentine. The saxonite is much more highly altered along the shear planes than elsewhere. The adit and the pits together have proved a zone of 35-percent chromite ore with a minimum width of about 5 feet.

Five small pits and trenches on the terrace below the adit show relatively small amounts of chrome ore in sheared and serpentized dunite. The best exposure, which is in the largest of the two upper pits and between 1,700 and 1,720 feet in altitude, shows from 40 to 50 percent of chromite on a surface 5 feet high and 6 feet wide, at right angles to the trend of the ore bands. The chromite is partly of the disseminated variety and partly banded. The layers of ore strike N. 35° W. and dip 40°-45° NE. Some of them are as much as 6 inches wide and contain high-grade ore. Between 15 and 20 tons of ore has been taken from this pit. The pits 40 feet downhill from this one show similar ore, though it is poorly exposed, and the ore may be continuous between these two sets of pits.

Three pits near the southeastern end of the claim show dunite with disseminated, lenticular, and banded chromite. The layers rich in chromite strike N. 30° E. and dip 35° SE. The pits are in a strongly sheared serpentized zone, which trends about N. 60° E. and dips 50° SE. This attitude is very different from that of both ore and shear zones in other places, and it may be a result of slumping. In the largest pit a face 5 feet high and extending 10 feet across the structure shows 40 to 50 percent of chromite, 20 percent of which is in high-grade lenses as much as 10 inches thick.

Black Cub No. 1 and No. 2 claims

The Black Cub No. 1 adjoins the Come and Get It claim on the south and lies northeast of the Black Cub No. 2. Small amounts of very low grade ore have been exposed in pits at the northwest end of this claim.

In the Black Cub No. 2 claim, on the southeast side of Baldface Creek, small amounts of rather high grade ore are exposed. At the side of the creek a lens about 20 inches thick

in the center is exposed for 10 feet vertically and 5 feet horizontally. The lens is sheared on the edges and represents part of a much larger kidney-shaped body. The one small pit on the claim shows thin-layered and disseminated ore. Specks of chromite scattered along a serpentine veinlet appear to have been introduced with serpentine.

Reserves

Because of inadequate exposures no satisfactory estimates of probable tonnage and grade of ore can be made for the entire Sourdough deposit. The amount of chromite seen in the natural exposures and the workings on the southern half of the Old Digings claim suggest that 50,000 to 100,000 tons of milling-grade ore may there be present. These figures are based on the assumption that the ore body is 20 feet wide and continuous throughout the length of the workings and that it extends to a depth at least equal to the vertical range of the exposures. No account was taken of probable offsets in the ore body, and chromite percentages can vary so much within a short distance that any estimates of them involve guesswork.

Recommendations for prospecting

Principles.--Prospecting and location of exploration pits in the Sourdough area should be undertaken only after careful consideration of the following facts:

1. Concentrations of chromite will be found only in dunite and in serpentine rock derived from dunite.

2. The ore will probably be of rather low grade, averaging less than 35 percent of chromite.

3. Although float is generally of great value in locating deposits, it may be unreliable in this area because of the presence of old river terraces, which are recognized by the red

soil that overlies them, between 1,520 and 1,700 feet above sea level. Accumulations of concentrated chromite float at such altitudes are likely to be the result of earlier stream action rather than ordinary downhill creep; and float found at lower levels may have come from these old terraces.

4. Chromite should especially be looked for along zones of shearing and serpentization; for the margins of layers especially rich in chromite are planes of weakness, along which much of the movement due to shearing occurs, and serpentization is especially marked along shear zones. The ore bodies are likely to be shattered by shearing movement.

5. It seems useless to attempt any mining in the area east of the claims because extensive landsliding has occurred there.

Procedure.--The extent of an ore zone might be pretty well determined by the following procedure.

1. Trenches at right angles to the trend of the ore zone should be dug at intervals of 100 feet or less between the adit and the southern end of the Come and Get It claim and also in the northern half of the Old Diggings claim. Stripping should be done between the trenches that show minable ore and at any other place where it is likely to reveal ore.

2. If a continuous ore body is revealed by this trenching and stripping, the richer portions should be tested to some depth by diamond drilling.

The showing in the two big pits on the Old Diggings claim could be tested to a depth of about 50 feet by four diamond-drill holes on the claim. If these holes showed that a thickness of 20 feet persisted to this depth, then reserves of about 20,000 tons might be regarded as probable and 10,000 tons more as possible.

BRIGGS CREEK AREA

Geography and history

The Briggs Creek chromite deposits are on Chrome Ridge, which is in Josephine County, Oreg., and in the north-central part of the Kerby quadrangle. Most of them are in secs. 11, 14, and 23, T. 36 S., R. 9 W. The area is about $2\frac{1}{2}$ miles as the crow flies but 5 miles by trail west of Ferren Guard Station, from which a forest road leads to Hayes Hill Station on the Redwood Highway. This road is impassable when wet.

The region is very rugged. Chrome Ridge forms the divide between the Briggs Creek-Illinois River drainage on the southeast and the Todd Creek-Rogue River drainage on the northwest. From the broad rough crest of the ridge, 3,800 to 4,500 feet above sea level, the ground falls abruptly about 1,800 feet to the streams. Briggs Creek is perennial and has a large flow.

During the World War the Briggs Creek camp was fairly active. An aerial tram extending from Chrome Ridge southward across Briggs Creek to the next ridge was constructed, 5 miles of road was built, and mining was begun. But at the end of the war, which came before any chrome had been shipped, the equipment was pulled out, and no mining has been done since.

A topographic and geologic map (pl. 71) of an area 2 miles long and 1 mile wide was made during the first 2 weeks of October 1939, under the direction of F. G. Wells. The eastern half of the area was mapped by L. R. Page, Martin Koenig, and W. M. Furnish, the western half by H. L. James and Robert Yates. The entire area was mapped on a scale of 400 feet to the inch, and the most promising prospects were mapped on a scale of 20 feet to the inch. Sketch maps of economically important workings were made with tape and compass.

Geology

The chromite deposits of the Briggs Creek area are all in the southern part of a sill-like mass of peridotite, which was intruded into hornblende schists and gneisses and thin-bedded quartzites.

The peridotite together with the included ore bodies was fractured by shearing in a northwesterly direction and was then serpentized. At the eastern contact of the main body of peridotite a mass of schistose serpentine rock 600 to 1,000 feet wide was formed. With this exception alteration to serpentine was confined to brecciated shear zones, thin layers along fractures, and the olivine-chromite contacts in some of the ore bodies.

The chromite deposits, which are partly of the pod or high-grade type and partly of the disseminated or low-grade type, are small and are widely scattered throughout the western half of the easternmost peridotite mass. No definite trend of the ore bodies is apparent beyond the limits of the prospect pits.

Metamorphic rocks

Distribution.--Several areas of metamorphic rocks, mainly amphibolite and quartzite, occur in the tract that was mapped. Two small areas, doubtless connected, lie on the ragged eastern edge; a small patch lies about a quarter of a mile east of Chrome camp; a larger one, which may be called the Chrome camp area, underlies Chrome camp and the valley to the south; and the margin of another area, of unknown extent, lies on the western slope of the west ridge. The different kinds of metamorphic rock are distributed in longitudinal bands, those of quartzite being especially well defined. This distribution indicates that the rocks were originally stratified. The amphibolites may be recrystallized lavas or volcanic sediments.

Lithology.--In the small area east of Chrome Ridge the exposures are poor, but these and the float show that three kinds of rock are present. The most abundant is a banded hornblende-feldspar diorite gneiss. A rock that is similar to this but that contains more hornblende, is finer-grained, and apparently is not schistose is exposed at one place. A cream-colored cherty quartzite was recognized by float only.

The most abundant rock in the Chrome camp area is a coarse-grained banded gneiss, which contains a little quartz but consists mainly of green hornblende and a feldspar that seems to be albite. On the weathered surface, well-formed crystals of hornblende stand forth in bold relief from a matrix of crushed and ill-formed grains of feldspar. The hornblende crystals in places have an alinement that cuts across the banding at an angle of less than 5° . A massive rather fine grained amphibolite composed of dark hornblende is associated with the gneiss and grades into it. All along the eastern margin of this Chrome camp area there is abundant float of thin-bedded quartzite but no outcrop.

The western area was studied only at the contact, where it consists of intergrading amphibolite and feldspar-hornblende gneiss.

Contact zones.---The metamorphism in these rocks is mainly regional and is nearly uniform except within a short distance of their contacts with peridotites. Near the contacts, intense igneous metamorphism has been superposed upon the regional metamorphism. The excellent exposures along the east side of the Chrome camp area show a sharp contact in a few places, but elsewhere thin bands of peridotite and country rock alternate in an indefinite zone about 250 feet in greatest width. The included country rock in many places is recrystallized to a very coarse grained mass of hornblende crystals, some of which are as much

as 2 inches in length. On the west contact of the area included fragments of hornblende-feldspar rock contain hornblende crystals as much as 4 inches in length. These crystals commonly lie at an angle with the schistosity that is due to regional metamorphism. Most of the contact along the western ridge is relatively sharp, although near the south end of the ridge the contact zone widens; some of the coarse hornblende rock is here exposed.

Ultrabasic intrusive rocks

Two areas of ultrabasic intrusive rocks, which may in general be called peridotites, are present in the district mapped. The main boundaries of the areas are elongated in a north-northeasterly direction, parallel to the banding in the adjacent metamorphic rocks, and the actual contacts, wherever they were seen, are parallel, or nearly so, to the banding in the metamorphic rocks. The ultrabasic intrusive bodies thus appear to be sill-like in general form. Topographically the ultrabasic masses stand out as prominent barren ridges, in sharp contrast to the subdued, brush-covered areas underlain by the metamorphic rocks. At least 95 percent of the ultrabasic mass is an olivine-pyroxene rock, in which the pyroxene appears to be enstatite, so that the rock is classed as saxonite. The proportion of olivine ranges from about 60 to nearly 100 percent, and some of the nearly pure olivine rock should be classed as dunite.

Saxonite.--On fresh fracture the saxonite is a mottled green. The dark cleavage faces of the enstatite stand out in sharp contrast with the lighter muddy green of the granular olivine and have the appearance of phenocrysts, although the crystal size of both minerals is about 2 or 3 millimeters. All the olivine is at least partly altered to serpentine, much of

it being completely replaced, and some of the enstatite is altered to a flaky pale translucent mineral. On the weathered surface the rock is fawn-colored and the pseudomorphs after enstatite are conspicuously lighter in color than the matrix.

East of Chrome Ridge the saxonite encloses many thin lenses, clots, or layers of dunite or of rock containing so little pyroxene that it might be classed as dunitic saxonite. West of Chrome Ridge pure olivine rock is relatively rare.

Dunite.--Most of the dunite is nearly black on fresh fracture, and its texture is obscure. The olivine is almost entirely altered to serpentine. Chromite, together with the chromium-poor spinel, picotite, is present as an accessory mineral; it is mostly disseminated but is locally concentrated in lenses.

Only a few of the areas of dunite are large enough to be mapped. On the west ridge is a well-defined dunitic layer within the saxonite, lying roughly parallel to the metamorphic-igneous contact. Most of the dunite appears to form clots, having gradational limits, in the saxonite. In the deep valley at the head of Briggs Creek there is an area of dunite, 600 feet wide and about 2,000 feet long, which trends about N. 40° W. The dunite is rather sharply separated from saxonite on the northeastern, southern, and western sides by shear zones. At its northwestern end it is in contact with hornblende schists, and its boundary here has a jagged course which would seem to be due at least partly to movement on faults of northwesterly strike. Fractures are closely spaced throughout this area, and weathered dunite fragments are rarely as much as 6 inches in diameter.

Dunite is characteristically the country rock of the disseminated chromite deposits, which are described later.

Structure.--The sill-like body of peridotite is believed, though hardly proved, to have been folded, together with the

metamorphic rocks, into a syncline whose axis trends northeastward through the middle of the largest area of serpentine, and it may also have been displaced by large longitudinal faults; but the verification of these beliefs must be left for the future.

The peridotite mass shows little internal structure. Some, but not all, of the dunite bodies are aligned parallel to the contacts between metamorphic and igneous rocks. At a few places on the west ridge, near the contact with the metamorphic rocks, a streaky distribution of the pyroxene has been noted, but it appears to be very local. Chromitic streaks are common in the dunite lenses, and although these streaks are not uniformly oriented it is probable that before shearing they were essentially parallel to the dunite-saxonite boundaries.

Both the igneous bodies and the schist have been displaced by faults of northwesterly strike, best exposed along the west side of the west ridge, where each of several faults has displaced the schist-peridotite contact horizontally from 50 to 250 feet. In most places the southwest block has apparently moved relatively northwestward. This movement has produced shear-breccia zones from a few inches to a few hundred feet thick in the peridotite, along which serpentization is prominent. Joints along which slight movement has probably taken place trend N. 10° - 30° E. and N. 70° - 90° E.

Chromite deposits

General features

The chromite ores of the Briggs Creek area are of two general types. The most abundant type is in general of low grade; it consists mainly of disseminated grains in dunite, which is either fresh or, more commonly, altered to a mass of talc, chloritoid, and serpentine, though it contains higher-grade

streaks. It is from such ore that the greatest production is likely to be made. The other type, of higher grade, forms pods, kidneys, and irregular masses along shear zones, usually in areas mapped as saxonite, although the rock within and immediately surrounding the ore is always dunite.

Eight samples of chromite-bearing material were carefully concentrated and the concentrates analyzed. The results are given in the following table.

Partial analyses of chromite in concentrates from
Briggs Creek area, in percent

[K. J. Murata, analyst]

	LRP-34-39	LRP-35-39	LRP-36-39	LRP-37-39
Cr ₂ O ₃	51.93	43.52	39.14	55.28
Fe ₂ O ₃	18.35	15.50	21.41	13.59
FeO.....	4.27	6.79	.65	7.89
Ratio of concentration.	68.4	69.0	43.6	40.9
	LRP-38-39	LRP-39-39	LRP-42-39	LRP-43-39
Cr ₂ O ₃	53.61	53.36	46.35	53.49
Fe ₂ O ₃	15.46	16.27	22.54	14.60
FeO.....	3.65	6.47	7.95	6.40
Ratio of concentration.	62.5	70.5	1.2	35.5

LRP-34-39. Grab sample from dump, 400 feet northwest of group 4.

LRP-35-39. Grab sample from ore in place in first pit in group 8.

LRP-36-39. Grab sample from ore piles in group 5.

LRP-37-39. Grab sample from dump at pit 35 by 22 by 5 feet described under "Other prospects," representing a 6-foot width of banded and disseminated ore.

LRP-38-39. Grab sample across banding representing a 6-foot width of banded and disseminated ore. From west face of third pit from the south end of group 1.

LRP-39-39. Grab sample from dump. Largely massive chromite with some orbicular and banded ore.

LRP-42-39. Grab sample from dump on the east side of the westernmost adit in group 3, on the north side of Brush Creek.

LRP-43-39. Grab sample of all exposed ore in pits northeast of the quarter corner of secs. 11 and 14, group 2.

The chromite has a high chromic-oxide content, but the iron content also is high. The highest chromium-iron ratio is 2.4, the lowest 1.3. Chromite that assays over 50 percent of chromic oxide has a chromium-iron ratio of 2 or greater. From the analysis and the ratio of concentration it is calculated that the highest-grade ore, LRP-39-39, assayed 38 percent of chromic oxide and had a chromium-iron ratio of 2.

The chromite is believed to be an original constituent of dunite. Some, at least, of the high-grade pods and masses along shear zones in areas that are dominantly of saxonite have shells of dunite, and it is possible that all the chromite was originally in dunite but that subsequent shearing caused the higher-grade bands to be segmented and shaped into pods.

Although the chief chromium mineral is chromite, minor amounts of uvarovite and kaemmererite have been noted. These two minerals occur mainly in the higher-grade ores that have been sheared, but kaemmererite occurs also in sheared disseminated deposits.

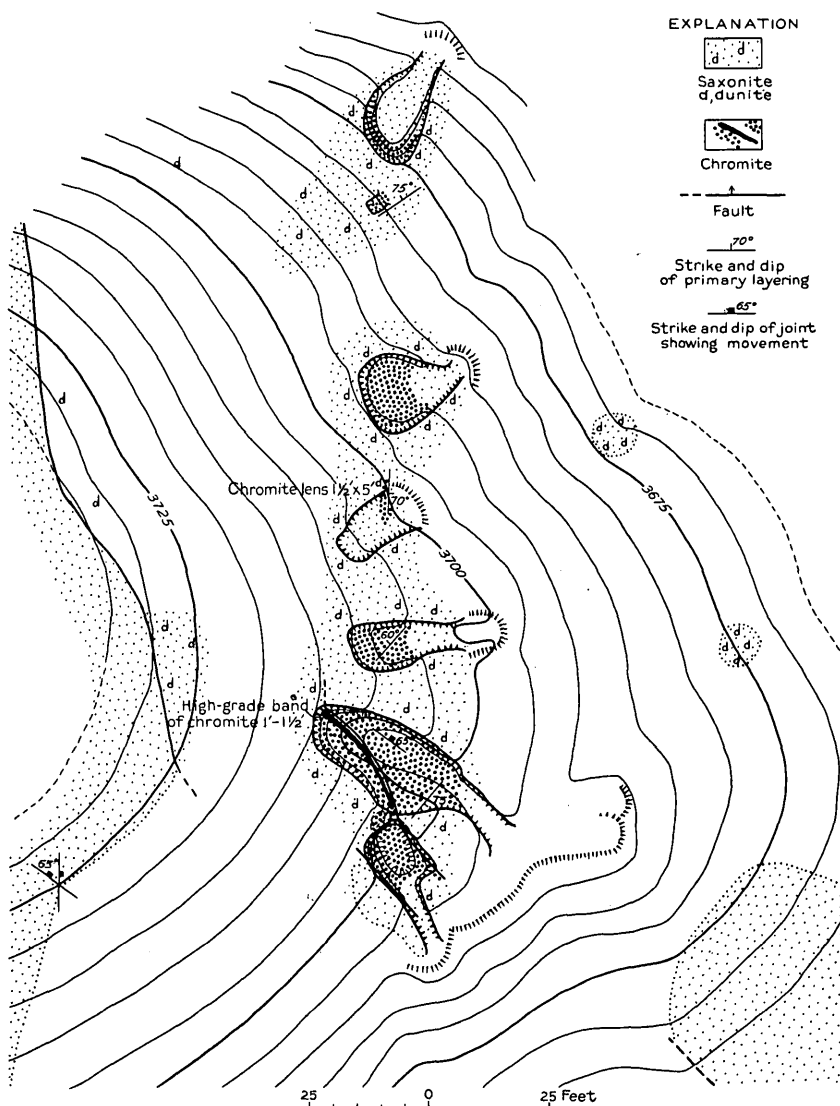
The original trend of the layers and lenses rich in chromite has been obscured by strong shearing in a northeasterly direction, as a result of which the ore bodies are more or less isolated.

The disseminated, or low-grade, deposits will be described first, and then the kidney, or high-grade, deposits. The deposits in each class are described in order of importance so far as it can be judged from present developments. The location of each deposit or group of deposits is indicated by a circle around an index number on the map (pl. 71).

Low-grade deposits

Group 1.--The largest and best-prospected body of low-grade, mainly disseminated chromite ore lies east of the upper

end of Chrome Road. A detailed map of the workings in this deposit was made with plane table and alidade. (See fig. 69).



Six pits and one caved adit cross the apparent trend of the ore body. These show much ore in an area 320 feet long from north to south and 25 feet wide, but the showings hardly prove a continuous ore body of these dimensions. In one pit only one kidney of chromite, 5 feet by 15 inches, was exposed

along a fissure. The entire area may be in a shear zone, the western limit of which is indicated in figure 69, and the ore body may thus be essentially a steplike series of fault blocks. The diversity of strike and dip in the chromite layers is probably a result of shearing. The strike of the ore layers in the three southernmost pits is about N. 40° E.; the dips range from 75° SE. to 60° NW. In the next pit north the ore strikes north and dips about 70° SE., being nearly parallel to a strong fissure that strikes north and dips 50° E. In the pits to the north the ore bands strike about N. 55° E. and dip 75° NW. All these readings are based on incomplete exposures, but they indicate that the ore, which probably had an original northeast trend, is much disturbed. The general northerly trend of the entire zone is probably due to faults of north-westerly strike, on each of which the north side shifted relatively westward.

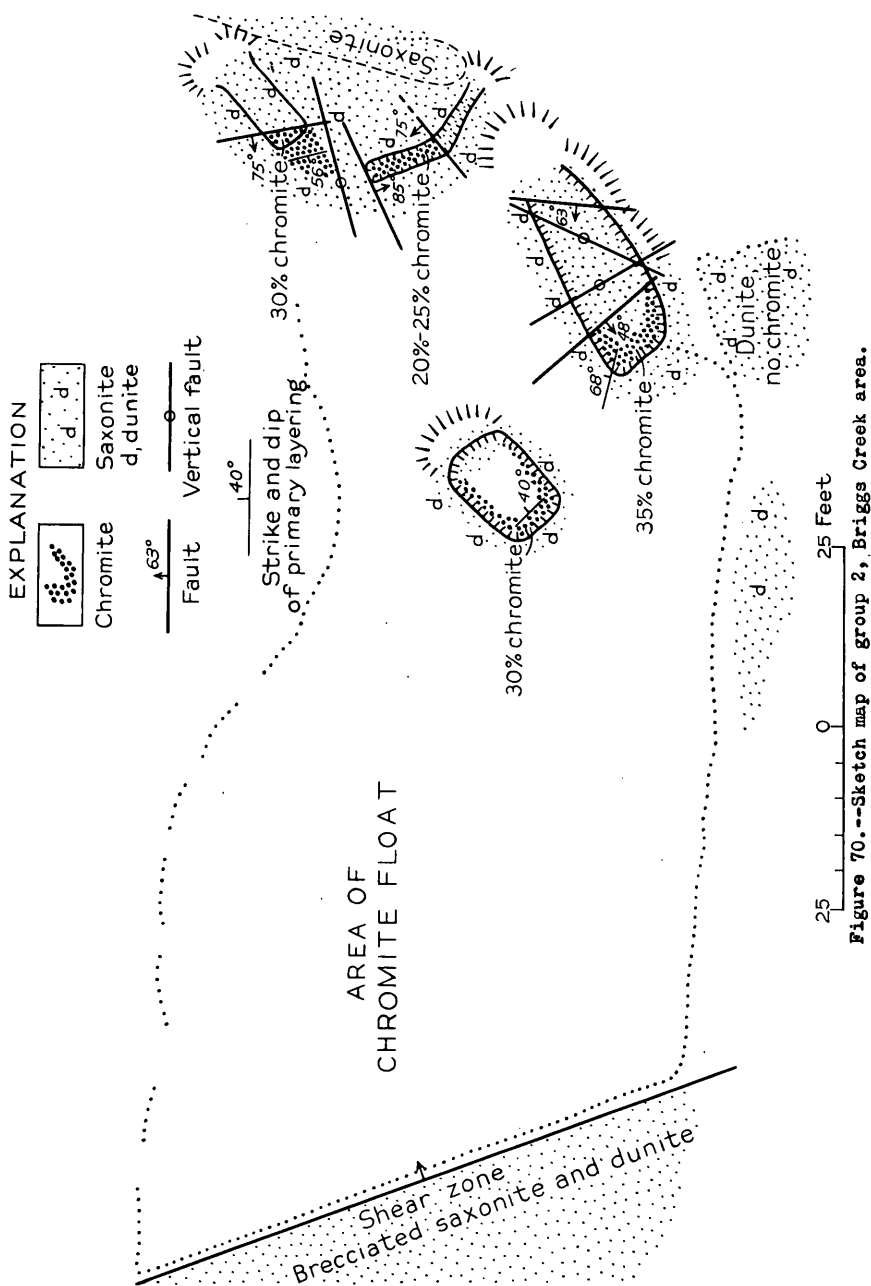
The country rock of this area is somewhat serpentinized dunite. The chromite is partly disseminated in grains one-sixteenth to one-eighth inch in diameter, partly concentrated in high-grade layers from half an inch to 6 inches in thickness. These layers contain from 70 to 100 percent of chromite, but the average ore has an estimated tenor of 30 or 35 percent. In much of this area a zone 15 feet wide consists of high-grade ore. The ore grades into dunite containing 1 percent of disseminated chromite. The two southernmost pits show high-grade pods as much as 15 inches wide and 6 feet long which, though located along fissures, have not been crushed and disintegrated by shearing. This ore is similar to that in the lens noted in the pit fourth from the southern end of this group and resembles some of the kidney ores.

The dumps and ore piles contain 50 to 75 tons of ore estimated to contain more than 60 percent of chromite and at least

as much more that would average between 10 and 30 percent. To estimate the reserves is very difficult because of the effects of shearing, but it is believed that these pits have proved about 4,000 to 5,000 tons of 30-percent ore. This estimate is based on the assumption that the minable ore is 15 feet wide. About one-third of this band would be high-grade ore containing over 75 percent of chromite. Because of the shearing of the ore, any reasonable estimate of the depth to which it may extend is impossible. Analyses LRP-38-39 and LRP-39-39 (p. 483) are of the chromite from this area.

Group 2.--East of the quarter corner on the north line of section 14 (see fig. 70) four pits and trenches have exposed a block of ore 40 by 65 feet to a depth of about 8 feet. These, like the previously described pits, are in dunite faulted against saxonite. The showings indicate at least 2,000 tons of ore containing 20 to 30 percent of chromite, and 2,000 tons more may be present. The shearing and dislocation of the ore body have obscured the extent of the ore in depth. Surface indications suggest that the ore probably does not extend horizontally much beyond the exposures in the pits.

The ore piles contain 20 to 30 tons, which average between 25 and 30 percent of chromite as a whole but include 3 or 4 tons containing 40 to 60 percent of chromite. Disseminated chromite that has not been prospected was noted to the north (see pl. 71). Another exposure to the southwest has been explored by a pit 6 feet by 2 feet, which reveals a 12-inch band of 40-percent chromite in dunite.



Group 3.--Three pits and two adits, one of which is caved, on the north side of Brush Creek and below Chrome Road, show disseminated and banded chromite in a large body of dunite. Scattered crystals of chromite are common in the dunite and in places make up about 5 percent of the rock. A sample obtained from the dump at the adit represents a similar very low grade ore. It is exposed along the entire length of the adit, which extends 30° E. for 36 feet.

The dunite is cut by fractures 1 to 4 inches apart. The adit follows well-developed fissures, which strike N. 30° E. and dip 85° E. These fissures are crossed by several others that strike N. 10° W. and dip 60° SW. and by a few that strike N. 20° W. and dip 70° SW. This adit was evidently driven to intersect the high-grade ore exposed in the pit 20 feet uphill but did not extend far enough to reach the ore body.

Ore dumps at this pit above the adit show 20 to 30 tons of ore containing 85 or 90 percent of chromite, taken from a high-grade layer 3 feet thick striking east of north. No definite direction of trend could be determined because of shearing on planes that strike N. 30° E. and dip 80° SE., but the general trend of the workings along this band is N. 50° E. Thinner layers of ore strike N. 38° E. and dip 55° SE. across the pit, which extends N. 10° E. and is 25 feet long, 10 feet wide, and 10 feet deep. The richest ore apparently forms a pod, which has been sheared. On either side of the high-grade ore there is 18 inches of 30- to 60-percent chromite, and the enclosing country rock contains about one-half of 1 percent of disseminated chromite. A streak 6 to 7 feet wide contains between 60 and 70 percent of chromite. Present developments indicate between 100 and 300 tons of 60-percent ore.

A pit farther west, extending N. 70° W., is 15 feet long, 8 feet wide, and 5 feet deep and gives an exposure, 15 feet

long and 3 feet high, of 10- to 20-percent disseminated and banded ore striking north and dipping 80° E. This includes a band of 40-percent ore. Prominent fissures strike N. 30° W. and dip 90° . The ore pile shows 5 tons of 30-percent ore.

To the west a pit 18 by 10 by 5 feet, with its long dimension extending N. 80° W., shows a 12-inch band of 80-percent chromite striking N. 30° W. and dipping 40° NE. This band is truncated by a fissure trending N. 80° E., which brings very low grade rock, containing about one-half of 1 percent, into contact with the high-grade chromite. Below the high-grade band is 3 feet of 5- to 10-percent ore. Well-developed shear planes strike N. 55° W. and dip 65° SW.; others strike N. 30° E. and dip 80° SE. The ore piles show between 5 and 7 tons of 80-percent disseminated ore.

The caved adit, east of the adit previously described, evidently was mainly in low-grade ore, although a little high-grade material is exposed near the portal. The relation of this high-grade band to that in the pits is not clear.

The workings in this group have uncovered more high-grade ore than other prospects in which the ore is mainly of the disseminated type, but it is too highly sheared and brecciated to allow an accurate estimate of reserves. Judged from present exposures, this group of prospects is not quite so promising as groups 1 and 2.

Group 4.--Southwestward across the head of Brush Creek from group 3 are three pits that expose similar ore. The lowermost and largest consists of two trenches 25 feet long, which intersect to form a V pointing up the hill. It is badly caved and shows no ore in place, but on the dump is 7 or 8 tons of ore containing 60 to 70 percent of chromite. This ore is in part banded, in part disseminated, and the country rock is dunite and dunitic saxonite. The main fissures fall into two systems,

one striking N. 35° W. and dipping 80° NE., the other striking north and dipping 55° E.

The pit above and to the east of this one is about 25 feet long and 15 feet wide and shows 5 feet of disseminated and streaked ore. One thin band of chromite strikes east and dips 50° N. The main fissures strike N. 45° W. and dip 70° NE., although one striking N. 70° E. and dipping 70° SE. is prominent.

The other pit of this group, elongated in a N. 40° E. direction, is 16 by 10 by 10 feet; it exposes banded, disseminated, and orbicular ore that apparently trends north and dips 80° W. The ore is cut by strong joints, of which some strike N. 40° E. and dip 50° E. and others strike N. 70° E. and dip 80° NW.

Other prospects.---Several other pits, scattered throughout the area, reveal only small quantities of disseminated ore containing as much as 20 to 35 percent of chromite, but they deserve mention as evidence of the widespread distribution of ore of this type.

East of group 4 and 35 feet north of the dunite-saxonite contact, a small pit, 6 by 1 by 2 feet, shows scattered grains of chromite, one-fourth to three-eighths inch in diameter, and orbicular masses in green massive serpentine. An obscure banding here strikes N. 45° E. and dips 50° SE. Most of the dunite exposures in this area show one-half of 1 percent of chromite.

A shallow pit, 35 by 22 by 5 feet, extending N. 20° E., is located on the south side of the ridge south of the head of Brush Creek. Slumping has covered the ore body, but piles of ore show 3 or 4 tons of 70-percent chromite ore and between 20 and 35 tons of 30-percent banded and disseminated chromite ore.

Two small pits located near the intersection of Chrome Road with the trail to Chrome camp show disseminated crystals as much as half an inch across and larger aggregates. These have been brecciated and the fractures in them filled with serpentine. This ore averages 5 to 10 percent of chromite.

High-grade deposits

Group 5.--The largest of the high-grade deposits (see fig. 71) is on the east side of Chrome Road at the head of Brush Creek. Almost no chromite was seen in place, but from workings

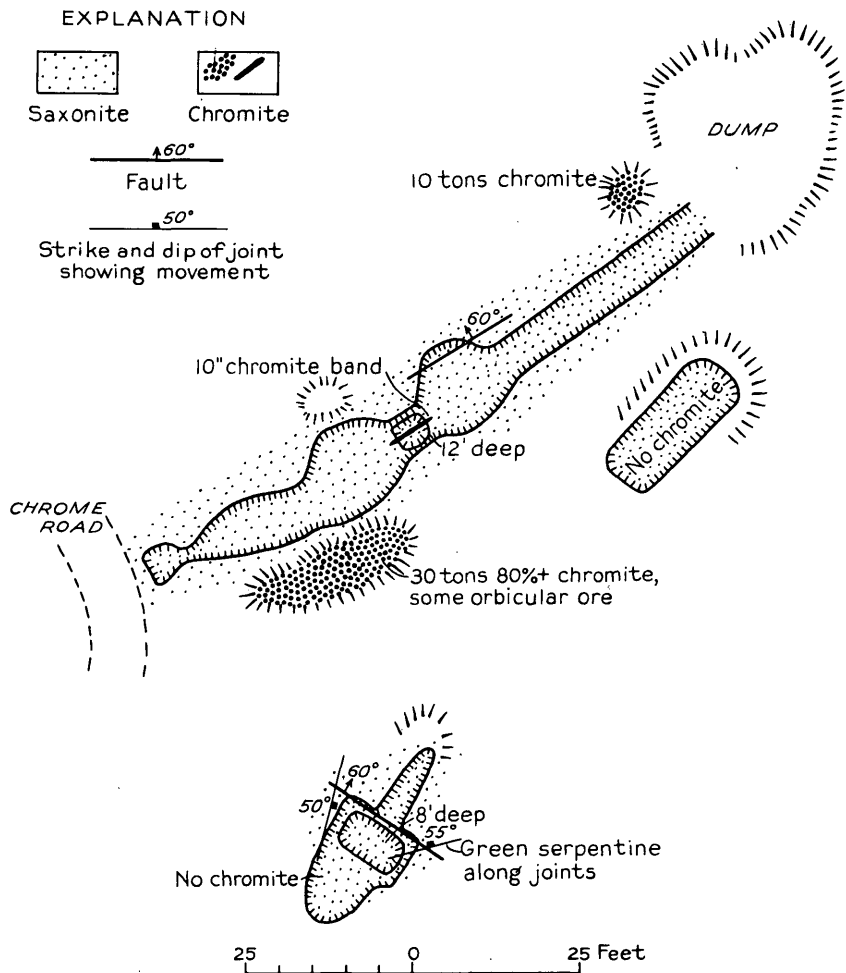


Figure 71.--Sketch map of group 5, Briggs Creek area.

and ore on the dump it is evident that this is the kidney type of deposit and that the ore masses are irregular in shape and distribution. It is estimated that this dump contains between 35 and 40 tons of high-grade orbicular chromite with occasional pieces of disseminated ore. Chrome chlorite is abundant and

occurs, with serpentine, along fissures in the saxonite country rock. A light greenish-yellow serpentine surrounds the chromite in the orbicular ore.

Two other small pits to the southeast show no ore, either exposed or on the dumps.

Group 6.--A pit 40 feet long, 10 feet wide, and 5 feet deep, just north of the trail to Ferren Guard Station shows high-grade ore on the dump but no chromite in place. Chrome garnet and chlorite are fairly abundant. The trench extends N. 20° W., apparently parallel to a shear zone. Well-developed joints strike N. 10° W. and dip 40° NE.

Group 7.--A group of five pits near the southwest corner of the area mapped shows a little kidney ore along fissures that strike N. 65° E. and dip 80° S. and along others that strike N. 35° W. and dip 70° SW., but it shows no ore along other fissures that strike N. 15° W. and in some other directions. These pits are not far from two pits that show disseminated and banded ore, containing 60 to 70 percent of chromite, in a band that trends N. 30° W. and dips 30° SW. It is possible that the kidney type of ore noted in this area was formed by shearing and displacement of banded ore.

Group 8.--A pit east of Chrome Road, about halfway between Brush Creek and group 6, exposes 8 to 10 tons of good high-grade ore, and its dump contains 20 tons of 5-percent chromite ore. The pit is 15 feet long, 10 feet wide and 8 feet deep. A small wedge-shaped drift extends N. 10° W. for 10 feet, suggesting that a large kidney of ore was removed. A layer of ore that strikes N. 20° W. and dips 70° NE. is exposed in the pit for a length of 10 feet. It contains lenticular masses of chromite, which are 1 to 3 feet long and have an average thickness of 10 inches and a maximum thickness of 2 feet. Serpentine slip-surfaces are abundant, and the character of the ore

suggests that the lenses were produced by shearing of banded chromite in dunite. Talcose serpentine gangue is characteristic of this body. Chromite float may be followed northward along the strike of this ore body for 100 feet.

A small pit, 6 by 1 by 3 feet, to the northeast of the one just described shows narrow bands of 60- to 70-percent chromite. The ore is granular and is in a gangue of talc and serpentine. Surface exposures show a zone 3 feet wide trending N. 20° E. for 20 feet but faulted on the north against saxonite by a fault that strikes N. 15° W. and dips 80° NE. This 3-foot zone would probably average 30 percent of chromite or less.

Group 9.--Four trenches lie about 1,000 feet southeast of Chrome camp. One extends N. 52° W. and is 45 feet long, 5 feet wide, and 4 feet deep; one extends N. 15° W. and is 60 by 5 by 4 feet; the other two extend N. 20° W.; one is 17 by 4 by 4 feet, and the other is 6 by 2 by 2 feet. A little ore was seen on the dumps of the two smaller trenches.

Group 10.--At an altitude of 4,010 feet on Chrome Ridge a pit extending N. 75° W., 12 feet long, 10 feet wide, and 3 feet deep, shows pods about a foot thick, of high-grade ore, enclosing a little chromium garnet, in shear zones that strike N. 75° W. and dip 50° N. These bodies are cut by north-south fissures.

Other prospects.--On the east side of Chrome Road and south of Brush Creek are nine scattered prospects, containing high-grade ore, that are not in any of the areas described.

At an altitude of 3,930 feet, a little west of group 8, are two trenches: the one to the northwest extends N. 30° W., and is 18 feet long, 5 feet wide, and 2 feet deep; the other extends N. 50° W. and is 17 by 9 by 4 feet. In the former a 12-inch layer dipping 70° - 90° NE. and containing 25 percent of chromite is exposed for 5 feet along the pit. About 150 pounds

of granular ore, containing 80 to 90 percent of chromite in a gangue of talc and kaemmererite, has been taken out. There are no exposures in the other pit, but the dump has 2 tons of high-grade ore.

Some 200 feet farther northeast, at an altitude of 3,960 feet, a pit extending N. 10° E., 15 feet long, 10 feet wide, and 6 feet deep supplied one ton of ore containing 50 or 60 percent of chromite in a gangue of serpentized dunite.

About 200 feet south of these pits and at an altitude of 3,915 feet, a trench extending N. 10° W. and 15 by 7 by 3 feet in dimensions was dug in serpentized saxonite but revealed no ore.

Four hundred feet northwest of group 8, at a 3,960-foot altitude, a U-shaped pit, extending for 10 feet along fissures that strike N. 30° W. and N. 5° E., shows banded ore striking N. 27° W. and dipping 25° NE. Most of the ore is in small lenses along fissures. On the dump are between 3 and 9 tons of ore containing 80 to 90 percent of massive granular chromite in a gangue of serpentine and talc.

Three other small prospects, each about 6 feet long, 3 feet wide, and 2 feet deep, lie at the head of the valley, north of group 8. In one pit small lenses of chromite lie along fissures that strike N. 27° W. and dip 60° SW. The ore is granular and has a gangue of talc, serpentine, and kaemmererite.

Two other small pits, one in section 23 and south of the area mapped, on the north edge of the valley of Briggs Creek, and the other extending N. 25° W., 15 feet long, 5 feet wide, and 4 feet deep, between it and Chrome Road, show disseminated ore along shear surfaces.

Reserves

The widely scattered deposits of this area give an over- favorable impression of the size and value of the chromite deposits. Prospecting of high-grade lenses near the surface give the impression that considerable ore is available, but the individual masses of ore thus revealed are small.

No large tonnage of disseminated ore assaying between 10 and 20 percent of chromic oxide, such as would clearly be worth concentrating, has been exposed by present development. Although the bodies of disseminated ore may have considerable vertical and horizontal extent and further trenching may indicate much larger tonnages than are now visible, the shearing of all such deposits in this area make them difficult to prospect and to mine.

If milling practice is developed that will make 1- or 2- percent ore profitable, the large dunite area in Brush Creek Valley might repay more detailed exploration.

