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CHROMITE DEPOSITS NEAR SEIAD AND McGUFFY CREEKS, SISKIYOU COUNTY, CALIFORNIA

BY

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CHROMITE DEPOSITS NEAR SEIAD AND McGUFFY CREEKS, SISKIYOU COUNTY, CALIFORNIA

By Francis G. Wells, Clay T. Smith, Garn A. Rynearson and John S. Livermore

ABSTRACT

The chromite deposits described in this report are in north-central Siskiyou County, Calif. They are in two long tabular masses of peridotite which lie end to end and trend north-northwest across the valley of the Klamath River. The Seiad Creek-Red Butte mass extends 10 miles north of the river and the Hamburg-McGuffy Creek mass 8 miles south. The outcrops of both are from 1 to 2 miles wide. The rocks that bound the peridotite on the east are thoroughly reconstructed schist and those bordering it to the west are less-metamorphosed volcanic and sedimentary rocks. The schists have been considered to be pre-Cambrian age, whereas the rocks to the west are probably of early Triassic age.

Strictly speaking, the chromite-bearing masses are complex bodies of ultramafic rock consisting mainly of dunite but also containing saxonite, lherzolite, pyroxenite and hornblendite (listed in order of abundance). Only the dunite contains chromite ore.

The tabular peridotite masses lie parallel to planar structures in the older rocks, but in their internal make-up no large-scale structural pattern has been recognized. The most conspicuous internal structure is the linear arrangement of the chromite-rich schlieren in the ore-bearing parts of the peridotite. A typical ore body may include parts made up of evenly disseminated chromite; the richest and largest bodies, however, are made up of concentrated, closely spaced chromite schlieren of different size, shape, and richness. Some schlieren contain 80 to 95 percent of chromite, but most of them contain 25 percent or less, and the ore must be concentrated to yield a marketable product.

Chromite is composed of chromic oxide, alumina, ferric oxide, ferrous oxide, and magnesia in different proportions. Hence the chromic-oxide content of pure chromites differ. It is consistently high for the chromite from this area as it ranges from 55 to 58 percent. The iron content is likewise consistently high, ranging from 14 to 21 percent.

. The total reserves of indicated and inferred ore as of May 1945 were 274,500 short tons, which would average 8 percent Cr_2O_3. The Seiad Creek mine (Mountain View group) contained the largest deposit; reserves amounted to 212,000 short tons. The McGuffy Creek mine contained 50,000 short tons of indicated and inferred ore. Four other deposits, the Emma Bell, Kangaroo, Mountain, Fairview, and Ladd, contain a few thousand tons of ore each.

INTRODUCTION

Location, means of access, climate.—The largest reserves of chromite in Siskiyou County, Calif., are found in two long tabular masses of peridotites called the Seiad Creek-Red Butte, and the Hamburg-McGuffy Creek masses. They lie end to end to form a discontinuous band of peridotite extending nearly 18 miles from the crest of the Siskiyou Mountains south by east across the canyon of Klamath River. The Klamath River is deeply trenched. The canyon sides rise in a distance of 6 or 7 miles from an altitude of 1,400 feet at the river to an altitude of 6,737 feet at the crest of Red Butte. The mountain tops have been glaciated and on them the rocks are well exposed.

The two hamlets located within the area, Hamburg and Seiad Valley, offer very little in the way of accommodations. The commercial center and county seat is Yreka, 52 miles by paved road to the east. Yreka is on a subsidiary of the Southern Pacific Railroad and on U. S. Highway No. 99, and here the Metals Reserve Company maintained a stockpile from 1942 to 1945.

The climate in Klamath Valley below an altitude of 2,000 feet is mild the year round, the season from October until late spring bringing rains, but on the crests of the mountains deep snows accumulate. There are numerous perennial streams and an abundance of water for milling. Timber for mining is available in many places.

History of mining.—The deposits of the district were located during the intensive search for chromite in the last years of World War I. Mining began in 1917, and a year later 10 mines were producing ore. Mining stopped when chromite prices collapsed at the end of the war. After about 2,750 long tons of ore had been shipped. Interest in the deposits near Seiad Creek and McGuffy Creek revived in the mid-thirties and the Rustless Mining Corp. bought groups of claims in both areas in 1937.

The rise of chromite prices in 1942 stimulated activity and both prospecting and mining were carried on until 1945. With the cessation of the hostilities of World War II interest in the deposits of the area subsided. Although it was early recognized that the ores must be concentrated in order to recover any large percentage of contained chromite, no mill has been erected in the district. By the end of 1944 the total shipments of hand-sorted ore amounted to 7,593 long tons.

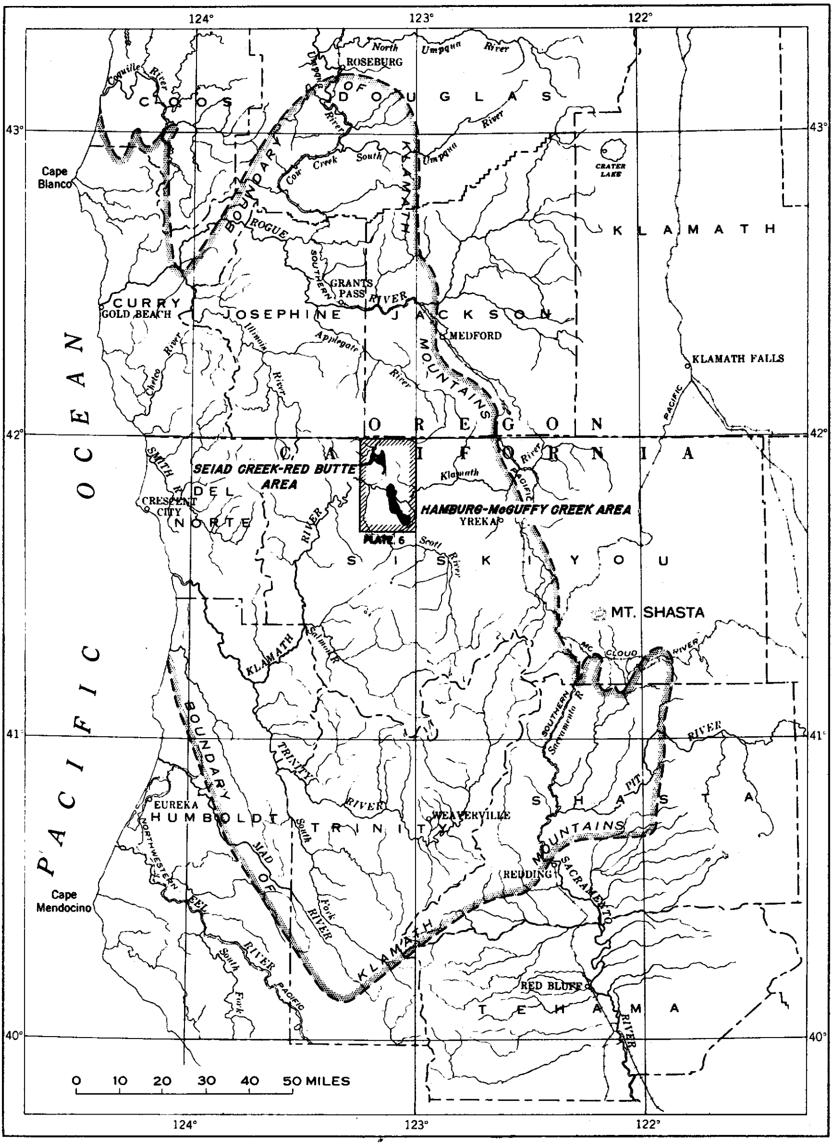

Figure 2.—Index map of northwestern California and southwestern Oregon showing location of Seiad-Red Butte and Hamburg-McGuffy Creek chromite areas and area covered by Plate 1.

<u>Basis of the report</u>.—In the summer of 1938, when studies of strategic mineral deposits were made possible by an allotment of funds by the Public Works Administration, this district was selected by the U. S. Geological Survey as a good example of the disseminated type of chromite deposits. G. A. Rynearson and C. T. Smith were assigned to make a geologic study of the area and the results of their work were published in 1940.1/

The Seiad Creek chromite deposits were then recommended to the U. S. Bureau of Mines for exploration and a joint project with the Bureau began in April and ended in October, 1941. Smith was reassigned to this project and prepared the final report on it. During the same season the Bureau of Mines systematically sampled the deposits on McGuffy Creek, and a Geological Survey party headed by John S. Livermore made a detailed geologic study of that area. A preliminary report was prepared by Wells and Livermore and a press release was issued. The following year the Bureau of Mines diamond-drilled the McGuffy Creek deposits, and Rynearson gave geologic supervision throughout the period of exploration from May 1 to the end of June.

During the autumn of 1941 a Geological Survey party headed by Livermore mapped the Kangaroo Mountain deposit. In 1942 Rynearson examined the Fairview and Ladd mines, which were being operated at that time, and the results of his investigations were issued as a press release. A topographic map of the Ladd Mine was prepared in September 1943.

The following geologists who have not been previously mentioned worked on one or more of these projects: John R. Bovyer, Fred W. Cater, Jr., Donald H. Dow, Leigh H. French,3d., Fred W. Gros, Robert T. Littleton, David A. Phoenix, Paul W. Richards, and William P. Williams. F. G. Wells was in immediate charge of all the Geological Survey projects and visited the properties at frequent intervals during the 5-year period. Although this report was prepared mainly by the senior author, it represents the combined efforts of all the authors and other geologists who participated in the investigations. The different deposits are shown on the plates and figures as they appeared when mapped during the periods outlined above; no attempt was made to bring all the maps up to one date.

<u>Acknowledgements</u>.—This opportunity is taken to thank the many local people who extended courtesies and cooperation to the personnel of the Geological Survey during the prosecution of this study.

The owners and operators, especially Mrs. Dorothea R. Moroney, Messrs. C. E. Tuttle, C. J. Hendrickson, R. H. Sayre, and W. P. Willard of the Rustless Mining Corp., and Mr. Edward Kubli, Mr. Philip Davies, and Mr. F. S. Pollock, have generously put their data at the disposal of the writers. The officials of the Klamath National Forest, especially Thomas Bigelow, Rex Denny, and Chester Bartholf, have been unfailingly helpful. The writers address their thanks to those mentioned and to the many others not named, as well as to their associates in the Geological Survey whose help contributed an important part to this report.

1/ Rynearson, G. A., and Smith, C. T., Chromite deposits in the Seiad quadrangle, Siskiyou County, Calif.: U. S. Geol. Survey Bull. 922, pp. 281-306, 1940.

GEOLOGIC SETTING

Introduction

The area under consideration is one of complex geology. The underlying rocks are all crystalline. They include two series; a more ancient and more thoroughly reconstituted series occupying the eastern part of the area and a younger series of less-recrystallized metavolcanic and metasedimentary rocks cropping out in the western part (see pl. 6).

The metamorphic rocks have been intruded by quartz diorite, the age of which has not been definitely established. Chromite-bearing ultramafic rocks occur chiefly between the two metamorphic series. Later granodiorite intrudes all these rocks and further complicates the geology by effecting contact metamorphism along its borders. Only detailed mapping will yield an adequate solution of this geology, but the work of Rynearson and Smith 2/ delimits the major features. These rocks will be described in this section in order of age, except that the ultramafic rocks will be described last in order to immediately precede the description of the chromite ores that they contain.

Rock types

Schists

The oldest rocks that crop out in the area are the hornblende, chlorite, sericite, and graphite schists that lie along the eastern flanks and wrap around the southern ends of both the Seiad Creek-Red Butte and the Hamburg-McGuffy Creek ultramafic bodies. The most abundant of these rocks are medium- to dark-green plagioclase-chlorite schists which presumably were formed by metamorphism of andesitic or basaltic tuffs. Much of the green schist is rich in epidote and small lenticular masses of quartz and coarse-grained calcite are abundant in some areas. At two places in the green schist, one near Hamburg and the other near Scott Bar, small deposits of good grade soapstone have been opened and utilized locally. A rock association that is common in the series is interlayered dark-gray to black graphitic schist with silvery white sericite schist containing small lenticular masses of quartz that lie parallel to the planes of schistosity. Thin bands of nearly pure quartzite are also interlayered with the graphitic and micaceous schists, suggesting that these rocks were derived from muddy sandstones. Detailed work done in some areas indicates that the schistosity is parallel or deviates only slightly from the original bedding. These schists are tentatively correlated with lithologically similar schists found in other parts of the Klamath Mountains, all of which have been classed as pre-Cambrian in age.3/

The foliation strikes from N. 40° E. to N. 25° W., and dips moderately or steeply either to the northwest or the northeast. Interbanding of the various kinds of schist suggests that they may be isoclinally folded. The contact of the schist and peridotite was observed in a few places. In one outcrop a small mass of schist enclosed in the peridotite near the main contact has been recrystallized to a coarse assemblage of garnet, magnetite, actinolite, and chrysotile. The general pattern of the

2/ Rynearson, G. A., and Smith, C. T., op. cit., pp. 284-289 , 1940.
3/ Hershey, O. H., Metamorphic formations of northwestern California, Am. Geologist, vol. 27, pp. 239-245, 1901.

contact of the schists and the Hamburg-McGuffy Creek ultramafic body indicates that the ultramafic body is essentially intrusive, though minor displacement may have taken place along it. The contact of the Seiad Creek-Red Butte body with the schist, on the contrary, appears to be a fault along most of its length.

Metavolcanic and metasedimentary rocks

Metamorphosed volcanic rocks that appear to be younger than the schists lie to the north, west, and south of the ultramafic intrusives. They extend north into the Grants Pass quadrangle where their original character is best determined. Amygdules and other volcanic structures are conspicuous; the series appears to have consisted mainly of andesitic and basaltic flows and sills, though it also contained thin layers of sandstone, tuff, and shale, and some thick layers of limestone. In general the only alteration that can be recognized in outcrop is the development of epidote and disseminated pyrite in the volcanic rocks and recrystallization of the limestone. In places, however, these rocks grade (along the strike or across it) into schistose plagioclase amphibolites, quartz-hornblende-plagioclase gneiss, quartz-mica schist, quartzite, marble, and lime-silicate rock, all of which are more coarsely crystalline and less distinctly foliated than the older schists previously described. They are thought to have been produced by igneous metamorphism of the rocks into which they grade. They are definitely Mesozoic and probably Triassic 4/ in age. They have been intruded by the ultramafic rocks, the quartz diorite, and the granodiorite. In general these rocks strike northeastward and dip northwest at angles less than 45°.

Quartz diorite

A body of quartz diorite surrounds the southern end of the Seiad Creek-Red Butte peridotite, and a similar body south of Seiad Creek is intrusive into the metavolcanics. The quartz diorite is probably older than the peridotite though it will take further field work to verify this relationship in the area. The quartz diorite is medium-grained and medium gray, and locally has a greenish cast. It consists mainly of andesine and quartz and contains a little biotite.

Gneissic structure resembling flow banding is common in the quartz diorite but is not conspicuous in all parts of it. It is particularly well exhibited along the west side of the West Fork of Seiad Creek, and is believed due, in part, to later deformation. Here, and also southwest of Hamburg, the peridotite is interlayered with the diorite to form a zone as much as 500 feet wide in which sheets of the two rocks alternate. Both the gneissic quartz diorite and the volcanic rock have been so intensely metamorphosed that in several places the contact between them is not readily recognized. These rocks, therefore, are not distinguished on some parts of the map, and much of the area near Canyon Creek and Devils Peak, mapped as younger metavolcanic rock, may be quartz diorite.

4/ Wells, F. G., and Hotz, P. E., Mesozoic volcanic series in southwest Oregon: Geol. Soc. America Bull., vol. 12, pt. 2, pp. 1937-1939, 1941.

A dikelike body of highly altered material similar to quartz diorite was found in the underground workings in the West Adit on the Mountain View claim No. 1. As it nowhere penetrates to the surface and was not found in any drill holes, it is thought it may be an inclusion or sliver of quartz diorite or quartz-hornblende-plagioclase gneiss engulfed in the peridotite at the time of intrusion.

Granodiorite

The granodiorite exposed in the area is a light-colored, medium-grained plutonic rock related to similar rocks that are exposed in the Grants Pass 5/ and Medford 6/ quadrangles to the north. It crops out east of the Seiad Valley and between Walker and Grider Creeks. The principal minerals are quartz, plagioclase, orthoclase, muscovite, and biotite. Considerable variations in the percentages of the different minerals result in facies that approach quartz monzonite and quartz diorite in composition. Inclusions of metamorphic rock that have a wide range of size and degree of assimilation are abundant in the border facies and some contain much garnet and lesser amounts of other contact metamorphic minerals. The granodiorite has a slight foliation and a definite cleavage. This rock is younger than the ultramafic rocks and older than those of the Chico formation (Upper Cretaceous) that rest on its eroded surface farther to the east.

Pegmatite

Small pegmatitic bodies occur within the main mass of granodiorite and as small irregularly shaped bodies in the peridotite (see pl. 27). This rock commonly has a white to bluish-gray color; it varies from a dioritic composition with very coarse hornblende and plagioclase crystals to a granitic rock composed primarily of quartz, plagioclase, and microcline, the feldspars often intergrown in a graphic texture. Biotite is usually present, muscovite less commonly, and occasionally garnet crystals are found. The pegmatite in the peridotite on McGuffy Creek contains black tourmaline.

Graphite

Small grains of graphite are found near the contacts of the ultramafic bodies. In general these grains are small, about 1 millimeter in diameter, or in other words the size of the chromite grains. Here and there, grains as large as a pea may be found. At four places within the ultramafic rocks graphite concentrations are sufficiently rich to have stimulated digging on them. The largest of these deposits and the one which has been explored most is located on the Black Jack group of claims on the crest of the Siskiyou Mountains (see pl. 6). Here the

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5/ Wells, F. G., and others, Preliminary geologic map of the Grants Pass quadrangle, Oreg. Scale, 1:96,000: Oregon Dept. of Geology and Min. Indust., (Text on back) 1940.

6/ Wells, F. G., and others, Preliminary geologic map of the Medford quadrangle, Oreg. Scale 1:96,000: Oregon Dept. Geology and Min. Indust., (Text on back) 1939.

graphite appears to be related to granitic dikes that cut the ultramafic rocks. The mineralization is largely localized in the pyroxenitic facies of the ultramafic rocks or occurs near contacts between pyroxenite and dunite. Some graphite, however, does occur in the dunite. The strike of the mineralized zone is approximately N. 40° W., with a dip of 50° S. This roughly parallels the foliation of the peridotite and the pyroxenite-dunite contact nearby. The graphite is of the crystalline type and some of the veinlets are high grade. A deposit in the McGuffy Creek area is localized in a fissure zone 5 feet wide which strikes N. 35° W., parallel to the structure of dunite. It also appears to be related to granitic dikes.

Ultramafic rocks (peridotite, serpentine)

Definition

The chromium ores of this district, like all known primary deposits of chromium ore, are contained in intrusive igneous rocks of the kind called ultramafic because they are extremely rich in magnesium and iron. The chief minerals in ultramafic rocks are the magnesium-and iron-rich silicates, olivine, pyroxene, and amphibole, and the commonest accessory minerals are the iron and chromium oxides, magnetite and chromite.

Peridotite is a general term for those rocks that contain only olivine and pyroxene, but the ultramafic rocks are divisible into intergrading varieties according to the proportion in which olivine, orthorhombic and monoclinic pyroxene, or hornblende were originally present. In this area four varieties are recognized:

(1) Dunite, consisting almost wholly of olivine with not more than 5 percent of pyroxene, which in this instance is the orthorhombic pyroxene, enstatite; (2) saxonite containing from 5 to 90 percent of enstatite; (3) lherzolite containing both orthorhombic and monoclinic pyroxene in excess of 5 percent; (4) pyroxenite containing 95 percent or more of pyroxene; and (5) hornblendite, a rock composed of hornblende with some olivine and augite.

The olivine, and to a less extent the pyroxene, are readily altered to minerals of the serpentine group. Rocks in which this alteration has been complete or nearly so are commonly called serpentine, and even where the alteration is only moderately advanced the resulting rocks are often rather loosely called serpentine.

Dunite

In general, weathered outcrops of dunite are characterized by a yellowish-red color, a smooth fine-grained surface, protruding scattered grains of chromite or magnetite, and an irregular jointing. Systematic jointing is well developed in one place in each mass, and in several places some of the dunite is coarsely crystalline. Crystals of olivine an inch in length have been found on Kangaroo Mountain. On Red Butte and Kangaroo Mountain coarse dunite weathers to a friable mass which breaks down into a very coarse grit. Dunite has a ragged uneven fracture but when largely serpentinized its fracture is conchoidal. The freshly broken rock varies from a light yellowish green to grayish green with a glassy to oily lustre when unaltered, to bluish green and greenish black with a waxy or corneous lustre when highly serpentinized. Thin seams of anthophyllite and fibrous serpentine a millimeter or more thick are common in places.

Under the microscope, dunite is seen to consist of irregular, interlocking angular grains of olivine which usually are from 0.5 to 1 millimeter in maximum dimension. Some of them are twinned and some show cleavages. Undulose extinction is also common. Careful study has shown that in part of the intrusive these grains are rudely alined with their longer crystallographic axes parallel.7/ Enstatite, augite, and hornblende are found in varying but small amounts. Small clusters and tiny veinlets of graphite flakes are widely scattered in the dunite in the Seiad Creek-Red Butte area. Usually about 25 percent of the rock mass is altered to serpentine. This occurs along cracks, cleavage planes, and as rinds partly or completely enveloping the olivine grains. Chromite grains also may be surrounded by serpentine, a fact of great importance in crushing the ore. Along zones of shear, the dunite may be completely serpentinized and even altered to talc and magnesite.

Narrow dikes of coarse dunite are found cutting older dunite, chromite, saxonite, or lherzolite.

Saxonite

Saxonite is a rock rich in olivine but containing more than 5 percent of the rhombic pyroxene, enstatite, as an essential constituent. Enstatite alters to bastite, a material having the composition of serpentine and a bronzelike metalloidal luster or schiller. Both enstatite and bastite weather less rapidly than fresh or serpentinized olivine, so they are left as projecting crystal grains exposed by the wasting of the fresh or serpentinized olivine and give a rough surface to the weathered saxonite which helps to distinguish it from dunite. In color, lustre, and fracture, the saxonite resembles the dunite in these intrusives, but the olivine is in general coarser-grained than that in the dunite and not as highly serpentinized (approximately 10 to 30 percent). The enstatite or bastite grains, also, are usually larger and in places they attain dimensions of several inches. On Kangaroo Mountain the pyroxene crystals increase markedly in abundance and size near the marble contact.

Lherzolite

A large part of the Hamburg-McGuffy Creek mass is a lherzolite. By definition lherzolite is a granular rock composed chiefly of olivine and containing both orthorhombic and monoclinic pyroxene as essential minerals, whereas saxonite contains the orthorhombic pyroxene only. The nature of the pyroxenes in most outcrops is uncertain, and as the two rocks are the same in all other characteristics, it is rarely possible

7/ Williams, W. P., Thesis submitted for the degree of Master of Arts to the faculty of Northwestern University, June 1944.

to distinguish them in the field. Furthermore they grade into each other. The rock in this area that is called lherzolite contains from 85 to 95 percent of olivine, a small percent of enstatite, a larger percent of clinopyroxene, either diopside or augite, and many specimens contain as an original constituent several percent of a pale-colored amphibole with optical properties similar to edenite.

Pyroxenite

Pyroxenite is exposed along the road on the south side of the Klamath River and is known to persist for some distance to the south along the eastern contact of the Hamburg-McGuffy Creek ultramafic mass. Its extent has not been mapped. The pyroxenite is a medium- to coarse-grained rock in which the strong cleavage of constituent minerals can be clearly seen in hand specimens.

The dunite, chromite, saxonite, and lherzolite are cut by later dikelets of pyroxene-rich saxonite ranging in width from a fraction of an inch up to about 1½ feet. Some of these dikelets are composed mostly of olivine but also contain large amounts of enstatite, whereas others consist mostly of pyroxene with minor amounts of olivine, and some are quite variable and range from one to the other. The olivine and pyroxene have been only very slightly altered to serpentine (5 to 20 percent).

Hornblendite

Small sills and dikes of hornblendite cut the peridotite. The hornblendite is green to greenish black on fresh surfaces and it weathers to a dark brown or green. The dikes are more resistant to weathering than peridotite and tend to stand out as narrow ribs or ridges usually only 2 to 3 inches wide. The dikes are not continuous for more than a few tens of feet. They are scattered throughout the peridotite mass, being notably abundant near the footwall of the mineralized zone at the Seiad Creek mine (see page 48). Thin selvages of hornblendite also occur in this area along the strike joints, cross joints, and planes of sheeting.

The hornblendite dikes are composed of pale-green hornblende with occasional grains of fresh olivine and augite. As edges of all grains are very distinct, it is not clear whether hornblende has formed at the expense of augite or is primary. There is no evidence of baking or alteration along the edges of the dikes, and the contacts are very sharp.

Composition of the ultramafic intrusions

The Seiad Creek-Red Butte and the Hamburg-McGuffy Creek masses have not been mapped in sufficient detail to determine the dunite areas from the rest of the peridotite except those dunite areas adjacent to the chromite deposits. From cursory examination of the other parts of the mass it is known that large bodies of the peridotite carry enough pyroxene to be classed as saxonite, but the Seiad Creek-Red Butte intrusive is dominantly dunitic. Most of the Hamburg-McGuffy Creek mass, on the contrary, carries enough pyroxene to be classified as a lherzolite or a saxonite and to the west of the Fairview Mine a large area consists of pyroxenite. Small areas of pyroxenite were also noted west of the Ladd Mine and in the eastern part of the Seiad Creek-Red Butte mass near the crest of the Siskiyou Mountains.

Contact effects of ultramafic rocks

The actual contact of ultramafic rocks with the enveloping rock can be seen at only a few places. In general the only features observed are those developed over a width of several feet. Exceptions are found on the West Fork of Seiad Creek and southwest of Hamburg where the contact zones attain a width of 500 feet and consist of alternating sheets of peridotite and gneissic diorite. This lit-par-lit structure is less distinctly developed in a narrow zone along the crest of the ridge trending north from Kangaroo Mountain. Here exposures are excellent, and it can be seen that the constituent amphibole minerals in the included layers of metavolcanic rock have been recrystallized to coarser grains. This feature is excellently exhibited elsewhere in the Klamath Mountains.8/

More unusual contact effects are exhibited in the large fragments of limestone and other sediments included in the peridotite in Kangaroo Basin. Time has not been available to make a complete study but it is known that metamorphism of these sediments produced coarse brown garnet, green actinolite, and feldspar. In places magnetite, large crystals of black and green amphibole, and chlorite have developed in the adjacent peridotite. Likewise crystals of magnetite as much as 1/8 inch in length have been developed in the schists along the southern peridotite contact exposed in Scott River Valley.

Structure of the ultramafic rocks

The structures of the ultramafic intrustions are of primary importance in the search for ore. The data on which knowledge of these structures is based are of two types, the small-scale areal mapping of the area, and the large-scale detailed studies of the ore deposits. The latter cover only a very small part of the intrusions. As the chromite is a primary mineral of the intrusive rocks, the structure of the ore deposits is part of the primary structure of the intrusives and, in fact, constitutes the largest part of the internal structures that can be detected in the field in these rocks of simple mineralogy and uniform grain. In the following discussion, the major structures of the ultramafic bodies and some of their minor internal structures will be described because they have more significance in the interpretation of the shape, size, method of emplacement, and deformation of these igneous bodies than they have to the structure of the ore bodies, which are small component parts of the main mass. Minor primary structures of the ultramafic rocks are described in detail with the descriptions of the ore deposits (see pp. 34-37).

8/ Wells, F. G., Page, L. R., and James, H. L., Chromite deposits in the Sourdough area, Curry County, and the Briggs Creek area, Josephine County, Oreg.: U. S. Geol. Survey Bull. 922, pp. 479-480, 1940.

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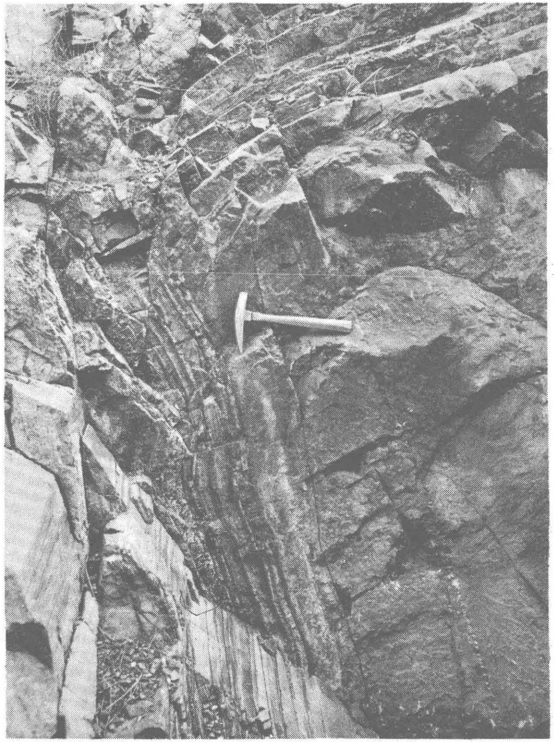
Shape and size.—Both the Seiad Creek-Red Butte mass and the Hamburg-McGuffy Creek mass, which are the hosts of the chromite deposits under consideration, are very well exposed. Slide rock and angular rock debris partially cover some of the lower slopes, but the upper slopes are bare. The Seiad Creek-Red Butte peridotite appears to be one mass with a large inclusion of younger metamorphics, but it may be two continuous bodies. Its outcrop (see pl. 6) is highly irregular in outline and has a maximum north-south length of 5½ miles. Its streamer-like extension along the crest of the divide is 7 miles long; the total mass has an outcrop area of 8½ square miles. The Hamburg-McGuffy body is a regular mass showing in its outcrop pattern the indentations up stream valleys characteristic of moderately dipping tabular bodies. It is 10 miles long and throughout most of its length maintains an outcrop width of 2 miles. It crops out over 18 square miles. The thickness of the mass is about 4,000 feet. Several small masses of peridotite crop out within the older and the younger metamorphic rocks and appear to be structurally independent of the two larger masses.

Both peridotite masses are sill-like bodies and lie parallel to the dominant planar structures in the older rocks which strike north-northwest and dip at various angles to the southwest and northeast. Throughout most of their extent the peridotites show no systematic major primary structures.

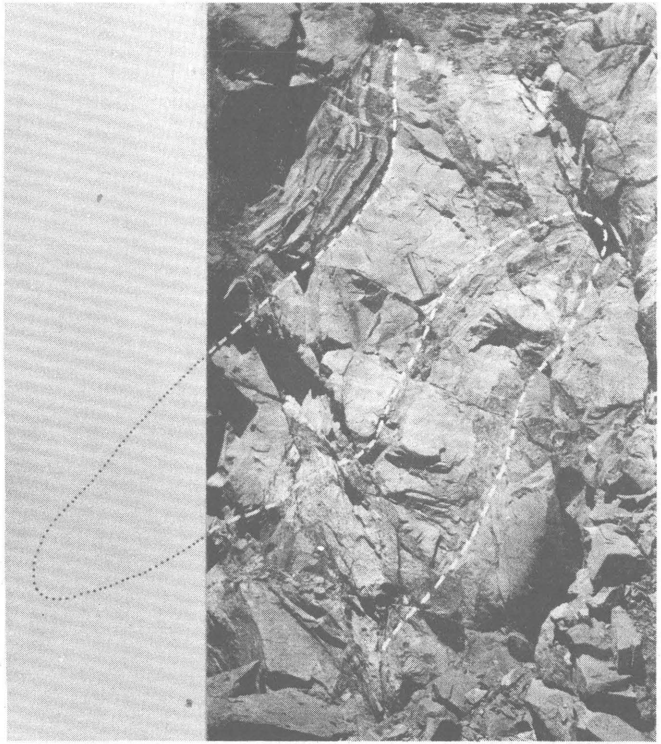
Contact relations.—At places along the contacts, layering of the peridotite parallel to the contact is poorly developed, and at other places the peridotite is interlayered with the enveloping dunite, metavolcanic rocks, or marble. Such lit-par-lit structure along the west contact of the Seiad Creek-Red Butte mass has been described on page 29. On Kangaroo Mountain the zone of lit-par-lit structures gives place to layers of recrystallized inclusions (see p. 29) and in places to a peculiar "pillow" structure which is accentuated by weathering. These "pillows" are irregular in shape and from 6 inches to 3 feet across. They lie with their long axes rudely parallel in a coarser grained peridotite which weathers out in small angular fragments ¼ inch across. This assemblage occurs in sheetlike layers parallel to the contact.

Folds.—The Seiad Creek-Red Butte peridotite mass appears to be in a large synclinal structure or synclinorium which extends north into the Grants Pass quadrangle.9/ Apparently the western part of the peridotite mass lies on the east limb and the Kangaroo Mountain area lies on the west limb of this synclinorium, but the precise position of the peridotite in the structure will remain uncertain until the area is mapped in greater detail. A small anticline which plunges steeply north is exposed in the metamorphosed sediments in Kangaroo Basin, and drag folding of the chromite layers in the peridotite is well developed in the Emma Bell claims.

9/ Wells, F. G., and others, Preliminary geologic map of the Grants Pass quadrangle, Oreg. Scale 1:96,000: Oregon Dept. Geol. and Min. Indust., 1940.



A. Fold in chromite ore on the Cerro Colorado claim. View looking southwest.



B. Drag fold in chromite ore on the Fairview No. 2 claim. The three limbs shown represent one continuous zone of ore. View looking north.

A. Platy jointing in dunite on the Mountain View No. 2 claim. View looking north.

B. Jointing in dunite on the Veta Grande claim. View looking southwest.

Whether the Hamburg-McGuffy Creek mass occupies a similar structure is uncertain. Such an interpretation is possible if faulting between the two masses is postulated. Folding of the peridotite on a small scale is clearly revealed by the chromite schlieren in the Cerro Colorado, Lady Gray, and Fairview claims (see p.57 and pl. 7 A and B). Small open flexures of narrow layers of chromite are common. Some of these are more closely flexed and resemble poorly developed drag folds. The axes of these folds on this claim parallel the linear elements.

Faults.—The boundaries of the Seiad Creek-Red Butte, and the Hamburg-McGuffy Creek masses are not offset by any faults of large displacement. Two large faults have been recognized within the peridotite in the McGuffy Creek area. Though the displacements along them cannot be determined, they are to be measured in many tens if not in hundreds of feet. They trend nearly east-west. A few faults of similar magnitude have been mapped in the Mountain View group of claims.

Faults of small displacement have been observed on both the Mountain View group of claims and the Cerro Colorado and Veta Chica claims, where they are revealed by displacements of the planar and linear structures of the chromite. Similar faults are present elsewhere in the peridotites but generally they elude detection. On the Cerro Colorado and Veta Chica claims these faults trend east-west; in general displacements along them are a few feet or less. Those on the Mountain View group of claims have somewhat greater displacement, but the average displacement of all faults mapped in these claims is probably between 10 and 50 feet. These faults can be divided on the basis of relative age into three distinct sets. The oldest are normal faults striking from N. 45° W. to N. 70° W., and dipping about 30° N. Closely associated with this set are later normal faults with the same strike but dipping about 45° N. The younger set is typified by the West End fault (see p.50) an oblique-slip fault with a sufficient strike-slip component to mask the reverse character of its movement. It follows that the direction of movement is parallel to the attitude of the linear structures. These faults strike about N. 75° E. and dip 45° N. Although most of the faults in the peridotite dip steeply, a few low-angle faults have been observed, and one such fault has been mapped at the Ladd Mine.

Joints.—Most of the peridotite is cut by random joints which divide the mass into irregular blocks. On Kangaroo Mountain a strong, widely spaced jointing (tens of feet apart) parallel to the contact (N. 20° to 38° E., dipping 60° to 75° NW.) can be detected when the rock is viewed from a distance of several hundred feet. The joints in this system cut across the unsystematic jointing and are masked by it. The dunite on the Mountain View claims is cut by a prominent system of joints that strikes N. 26° to 64° W. and dips 37° to 74° NE. (see pl. 8A). These joints are spaced from 1 or 2 inches to 6 inches apart and give the rock a platy structure, which is accentuated by a parallel platy structure of the chromite. A jointing at right angles is less well developed but serves to cut the rock into oblong plates.

The dunite in the McGuffy Creek area is likewise highly jointed. A dominant system of joints cuts the rock into a great number of many-sided prisms, the long edges of which trend N. 10° to 30° W., and plunge from 5° to 20° N. (see pl. 8B), parallel to the linear structure in the ore (see p.32). Other joints cut the prisms at right angles to the length at intervals of 6 inches or greater. In areas of abundant chromite the cross joints are accentuated by many parallel seams of chrysotile. These layers, which are a millimeter or less thick, are closely spaced, as many as 3 or 4 to the centimeter and though individual layers are not very widespread, the structure is. The joining is believed to be controlled by a primary structure in the peridotite, an alinement of its mineral grains.

Linear parallelism.—Linear parallelism, or "flow lines" as defined by Balk, 10/ is exhibited by many structures in the peridotite masses and is the most ubiquitous structural element in them—at least in the areas mapped in detail. It is most clearly shown by the parallelism of the rods of chromite seen in all the ore and by the parallelism of the major axes of the ellipsoidal nodules and orbicules of chromite (see pp. 60-61). It is emphasized by the jointing systems as well as by the folds as described above. This linearity as previously stated, strikes N. 10° to 30° E. with a 5° to 20° plunge toward the north in the McGuffy Creek claims, and N. 50° W. with a plunge of 10° toward the southeast in the Mountain View claims.

In describing primary flow structures Balk 11/ defines flow lines as "all linear structures that are believed to have resulted from more or less viscous flow of magmas." Further on he states, "basic clots were plastic for some time. Their slender, spindlelike form indicates the direction, and the degree of their elongation registers the extent to which the surrounding rock has been elongated. In zones where the surrounding rock minerals—for instance, phenocrysts—are rigidly oriented, the clots are drawn out into thin and slender streaks, the longest axes of which are parallel to the longest axes of the surrounding phenocryst. Likewise, phenocrysts within autoliths may share the same direction. If the surrounding minerals are less rigorously oriented, however, the clots are proportionately stouter, resembling slightly deformed spheres."

CHROMITE DEPOSITS

Ore bodies

Structure, size, and shape

The chromite deposits of the Seiad Creek-Red Butte and Hamburg-McGuffy Creek masses are concentrations of chromite grains similar to those found throughout the peridotite as accessory minerals. All degrees of concentration are found from dunite containing a few percent of scattered chromite grains, called disseminated ore, to aggregates of almost solid chromite, called massive ore. The most common type of aggregate is streaked or schlieren ore. These rich streaks—correctly

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10/ Balk, Robert, Structural behavior of igneous rocks; Geol. Soc. America Mem. 5, p. 10, 1937.
11/ Balk, Robert, op. cit., p. 10, 1937.

called schlieren 12/ —contain from 25 to 90 percent chromite by weight and are separated by almost barren dunite. Individual schlieren taper out and become ill-defined toward the ends and are most sharply defined at the sides. They have various shapes and frequently occur as single wisps or in groups of wisps like cirrus cloud formations.

The schlieren tend to lie in zones that consistently trend parallel to the elongation of the enveloping peridotite mass and have the same dip insofar as the dips of the peridotite masses are known. Individual schlieren commonly are closely spaced to form sheaflike or bundlelike masses rich enough to be classed as ore. These ore bodies range from a few feet to as much as 500 feet in length and are from 3 to 30 feet wide. Several of them may be spaced close enough that the whole group could be considered a minable ore body.

Several noteworthy zones of chromite aggregation have been found in the Seiad Creek-Red Butte mass. The largest of these is the Seiad Creek or Mountain View deposit. This deposit extends over a length of 1,300 feet, a width of about 250 feet, and about 250 feet down the dip. The Emma Bell zone consists of intermittent schlieren that can be traced along the strike for 3,000 feet and over a vertical range of more than 1,000 feet. The width of the zone does not exceed 100 feet. It consists of schlieren 1 to 5 feet thick, and at most 350 feet in length; some layers can be traced 50 feet down the dip. Much of the zone is barren.

The largest zone of chromite aggregations in the Hamburg-McGuffy Creek mass is on the Veta Chica, Cerro Colorado, and Grand Falls claims. This zone is about 2,500 feet long and about 100 feet thick. It seems probable that the zone would extend 200 feet or more down the dip. It should be noted that this zone has many parts in which the concentration of chromite is less than 2 or 3 percent.

These zones indicate the gross size of the deposits to be expected in the two masses. Extensions of schlieren may occur down the plunge of the zones and new comparable deposits might be found down the plunge of small schlieren.

Bodies of schlieren rich enough to be economically classed as ore form only a part of these zones. The tenor of any part of a zone is determined by the richness and the spacing of the schlieren. Although the boundaries of bundles of schlieren with normal dunite are not sharp and they may be fringed with a halo of disseminated chromite, the transition zone is narrow and the mass can be delimited. It follows that the size of an ore body is usually determined by the economic cut-off grade, although each deposit has an individual volume and tenor. The individual volumes may be defined as the total mass of disseminated or streaked ore separated from other ore by an amount of essentially barren dunite large enough to be left unmined; the individual tenor is the grade of this body. Ore bodies having individual volumes containing a few thousands to tens of thousands of tons and an individual tenor of from 3 to 5 percent

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12/ Schliere, an irregular portion, ordinarily not everywhere sharply bounded, of an igneous rock that differs in texture or composition from the rest of the rock mass but is an essential part of it. Plural schlieren. Fay, A. H., A glossary of the mining and mineral industry: Bur. Mines Bull. 95, p. 595, 1920.

are present in these masses. Bodies of ore that contain 20 percent chromite are present, as well as a few thousand tons of ore that could be cobbed to shipping grade, but no deposits consisting essentially of massive ore have been found. Three distinct masses of disseminated ore have been explored in the Seiad Creek-Red Butte mass and six others in the Hamburg-McGuffy Creek mass. These occur at the Kangaroo mine or Anniversary claim; the Stanton mine or Emma Bell group of claims; the Seiad Creek mine or Mountain View group of claims, in the Seiad Creek-Red Butte mass; the Ladd mine; the Hamburg Bar mine or the Fairview group of claims; the Black Spot claims; the Neptune claims; and the McGuffy Creek group of claims containing the Cerro Colorado, Veta Chica, the Veta Grande, the Piedras, the Mary Lou, the Lady Gray, the Grand Falls, Grand Canyon, and Bluestone. Many other small occurrences are known.

Localization of ore bodies

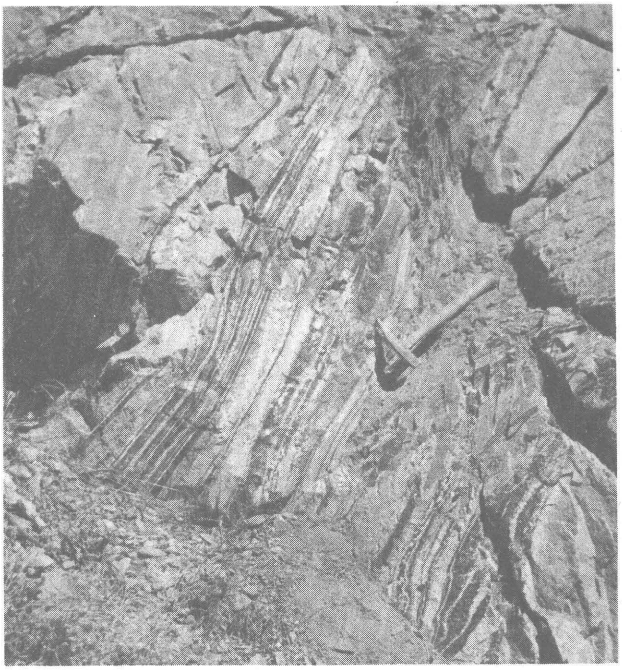
The chromite deposits of the district occupy various positions within the peridotite masses, and are not more commonly found in one part of them than in another at least insofar as the shape and structure of these masses are known or inferred. The largest deposits, the Mountain View claims or Seiad Creek deposits, appear to be located midway between the top and bottom of the east limb of the Red Butte-Seiad mass. The Anniversary claim or Kangaroo Mountain deposit is within a few hundred feet of the basal contact of the west limb, or else an inclusion in the west limb, but a distinct zone of schlieren lies less than 1,000 feet below the upper contact of this limb and other schlieren are known in various places within the mass, for example the Emma Bell ore. The McGuffy Creek deposits are located near the base of the Hamburg-McGuffy Creek mass, but the Ladd deposits and the Fairview deposits appear to be well within the mass.

Structure of the ore

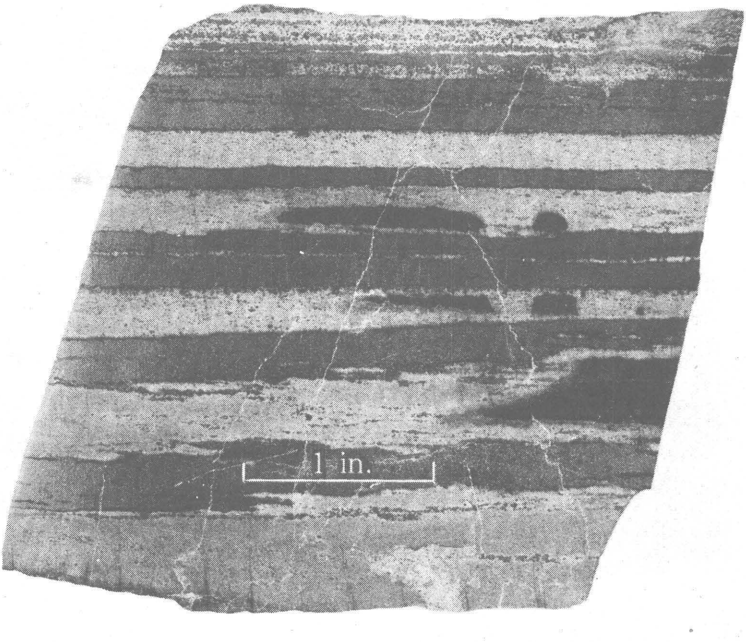
Seven more or less distinct structural varieties of ore are found in the district. They are (1) massive, (2) disseminated, (3) planar banded, (4) linear banded, (5) nodular, (6) orbicular, (7) boudinage. A description of each variety follows.

Massive and disseminated ore.—In massive and disseminated ore there is no apparent arrangement of chromite grains, and all possible gradations from a few scattered grains in dunite to aggregates of pure massive chromite are found. Euhedral chromite is common in the disseminated ores but most of the chromite is subhedral to anhedral. Anhedral rounded grains are not common. The grain size differs but the range is between 0.1 and 1.0 millimeter. Massive ore is not common in the area and nothing similar to the pod deposits so characteristic of the chromite deposits in Del Norte County is known.13/

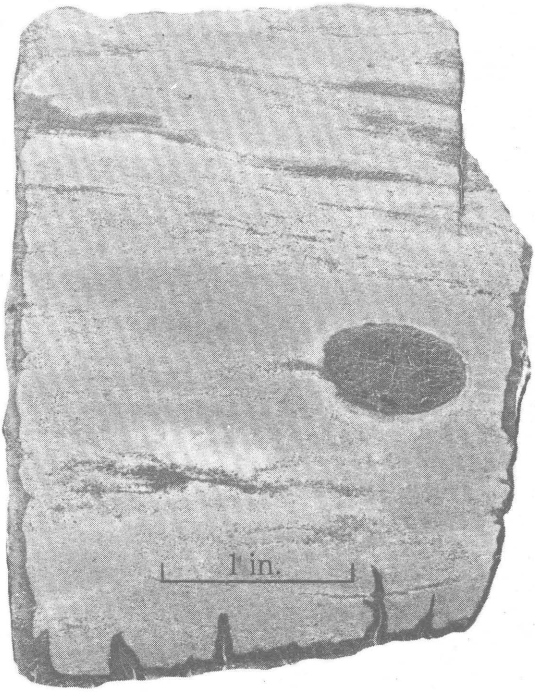
13/ Wells, Francis G., Cater, F. W., Jr., and Rynearson, G. A., Chromite deposits of Del Norte County, Calif: Calif. Div. of Mines, Bull. 134 pt. 1, ch. 1, 1946.



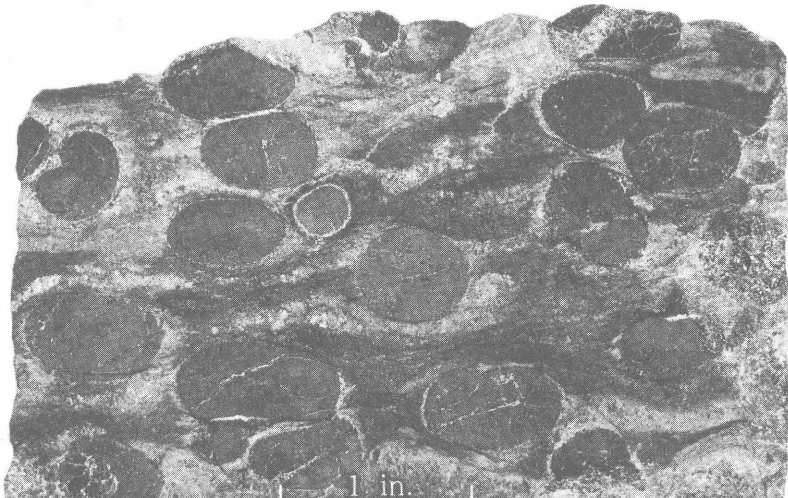
A. Planar banded chromite ore on the Fairview No. 2 claim. View looking northwest.



B. Planar banded chromite ore from the Veta Chica claim. The chromite is dary gray. The black patches are unweathered dunite.



A. Isolated chromite nodule in banded ore from the Grand Canyon claim.



B. Nodular chromite ore from the Black Spot No. 1 claim.

Planar banded ore.—Banding is developed to some degree in nearly all the exposures of ore. Planar banded ore consists of alternate layers of high- and low-grade ore. It is best shown on the Veta Chica claim, McGuffy Creek area, the Fairview mine, and the Mountain View No. 2 claim, Seiad Mine, where layers of almost solid chromite, usually an inch or less thick, alternate with layers of partially serpentinized dunite containing sparsely scattered grains of chromite (see pl. 9). Commonly a group of several closely spaced layers are separated from a similar group by a few feet of barren rock. The bands taper out and become ill-defined toward the ends and are most sharply defined at the sides. They are of variable width and continuity. Layers of massive chromite up to 8 inches thick have been observed and narrow layers can be traced along the strike for 30 feet or more before they grade into dunite or are sharply terminated. Exposures are such that it usually is impossible to follow layers more than 15 feet down the dip and it is believed they are not as continuous in this direction. The contacts of the layers appear sharp and straight to the unaided eye, although adjacent grains of chromite and olivine are interlocked.

Linear banded ore.—Linear banded ore is very common and, together with the planar banding, characterizes most of the ore in the area. When observed parallel to the strike, linear banded ore has the same appearance as the planar banded ore, but when viewed across the strike it is seen that the banding is formed by a series of parallel rods of chromite in nearly parallel layers (see fig. 3). The attitude of the linearity : consistently parallel to the elongation of the peridotite bod;

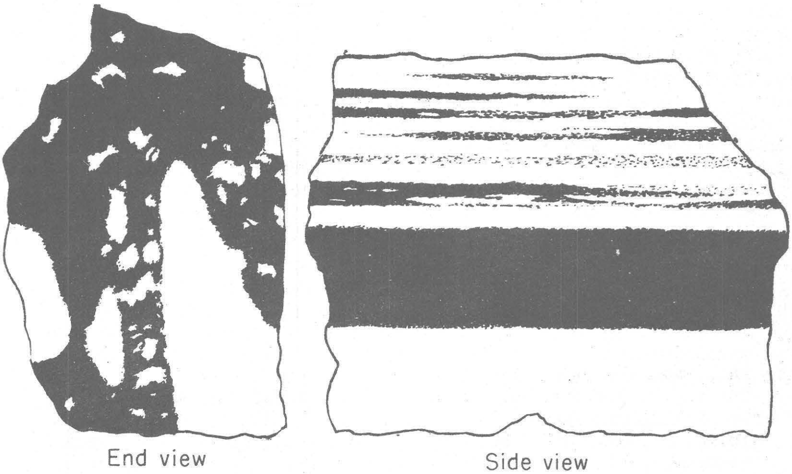


Figure 3.—Sketch of linear chromite schlieren (black) in partly serpentinized dunite (white). Drawn to scale.

Nodular ore.—Nodular ore has been found only on the Black Spot claims and the Grand Canyon claim in the McGuffy Creek area. It consists of rudely spherical or ellipsoidal nodules of chromite which are from three-eights to three-quarters of an inch in diameter and are surrounded by partially serpentinized olivine. The major axes of the nodules are parallel to the other linear structures (see pl. 10).

Orbicular ore.—Orbicular ore occurs only on the Mary Lou, formerly the Octopus, claim. The orbicules are ellipsoidal units, each of which consists of a nucleus of coarse-grained chromite surrounded by a shell of partially serpentinized olivine which in turn is rimmed by a thin outer shell of fine-grained chromite (see pl. 11). A few orbicules have two or more alternate shells of chromite. Some shells are bent in, others are flexed in place and have an S-like form in longitudinal section. Units as much as 2½ inches long and ½ inch in diameter have been measured. In most specimens the orbicules are closely packed in parallel orientation with a little chromite between the units, but in a single small specimen the interstitial chromite is more abundant than the nuclear chromite. Johnston 14/ has suggested that this structure indicates two or more generations of chromite; the finer-grained matrix surrounding the orbicules has crystallized later than the chromite in the nuclei. These ellipsoids also have their major axes oriented parallel to the other linear elements in the peridotite. The major axes are parallel to the plunge and the intermediate axes are parallel to the dip.

Boudinage structure.—A boudinage structure is developed in some of the ores at the Fairview mine and at the Emma Bell claim. This type of structure was named boudinage by Lohest 15/ after an occurrence at Bastogne, Belgium (see pl. 12), and its origin has been discussed by several geologists.16/ The type example consists of a series of barrel-like structures laid end to end in the direction of dip of the formation in which it is developed. Less well developed examples resemble a string of sausages, as exemplified in the ore from the Fairview mine (see pl. 13). Wegmann 17/ believes that boudinage structures are developed under conditions of stretching in a sequence of more mobile and less mobile beds. The boudinage is developed in the less mobile beds and according to Wegmann 18/ is frequently formed on the under limb of an overturned fold. It is reasonable to assume that the layers of chromite grains consisting almost entirely of

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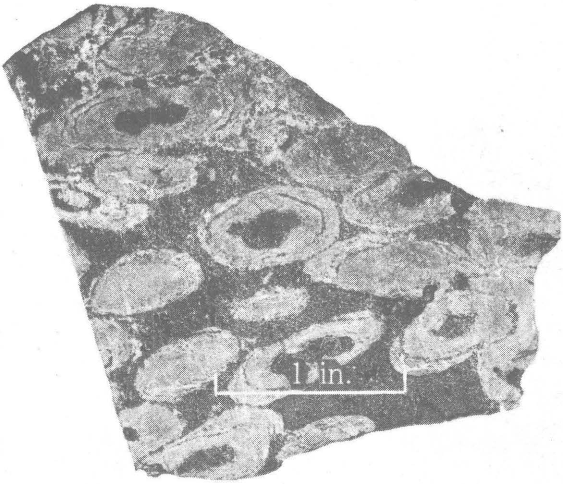
14/ Johnston, W. D. Jr., Nodular, orbicular and banded chromite in northern California: Econ. Geology, vol. 31, pp. 418-421, 1936.

15/ Lohest, M., Stainier, C., and Fourmarier, P., Compte rendu de la Session extraordinaire de la Société géologique de Belge: Soc. belge geologie Ann., vol. 35, pp. 351-434, 1909.

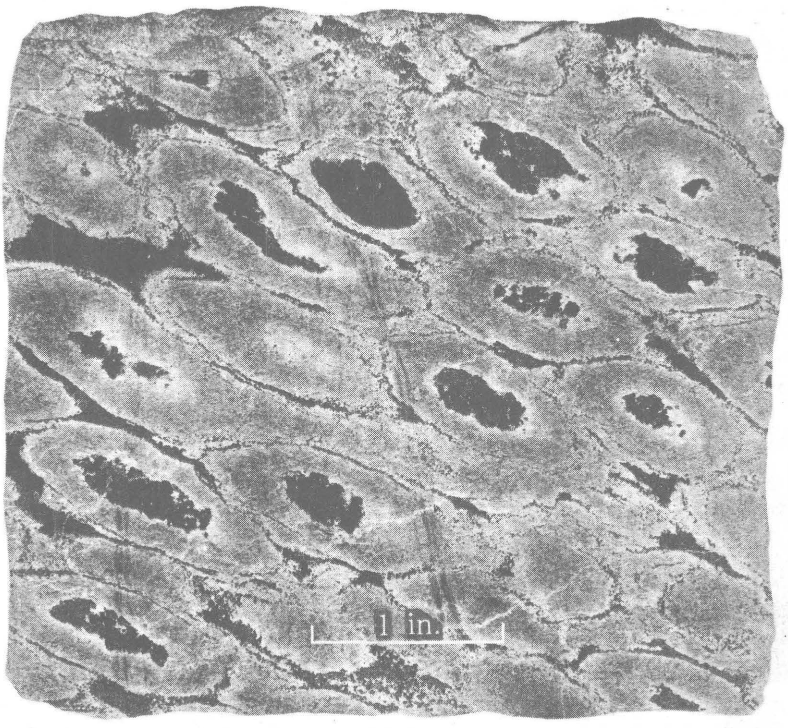
16/ Quirke, T. T., Boudinage an unusual structural phenomenon: Geol. Soc. America Bull., vol. 34, pp. 649-660, 1923.
Corin, F., Soc. belge géologie Ann., vol. 54, pp. 413-455, 1932.
Wegmann, C. E., Note sur le boudinage: Soc. géol. France, Bull., 2. serie 5, pp. 477-491, 1932.

17/ Wegmann, C. E., op. cit., p. 481, 1932.

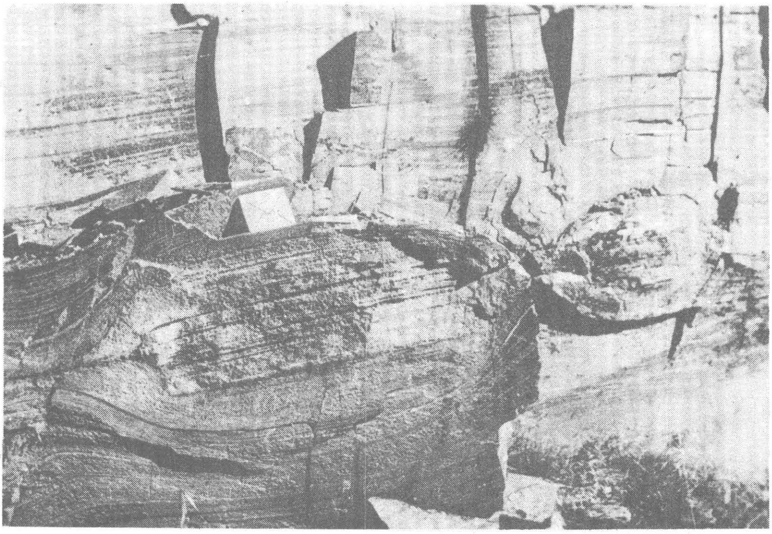
18/ Wegmann, C. E., idem, p. 485, 1932.



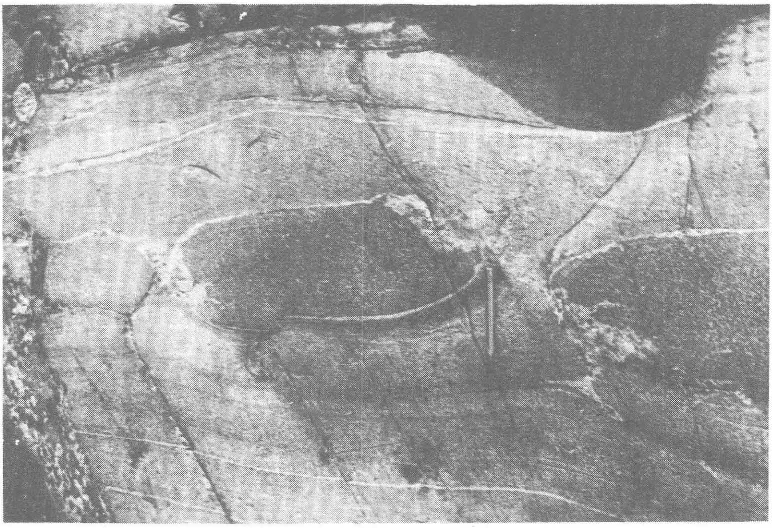
A. Orbicular chromite ore from the Mary Lou claim. Note successive shells of chromite and the abundance of inter-orbicular chromite.



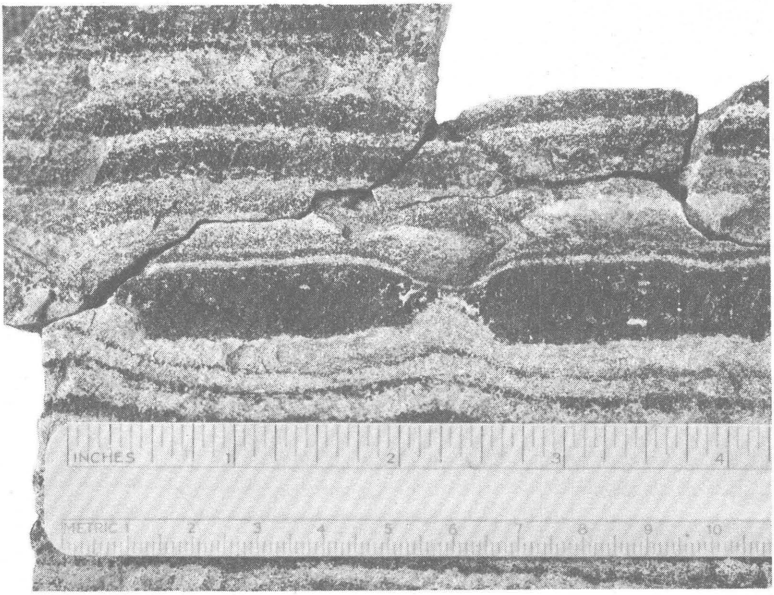
B. Orbicular chromite ore from the Mary Lou claim.

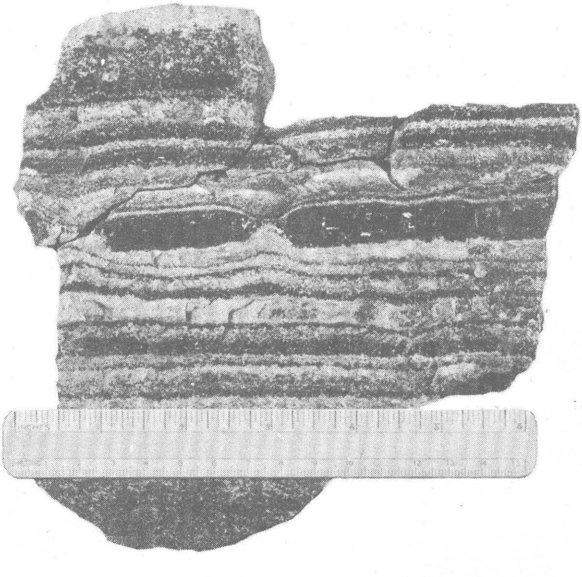


A. Amphibolite boudinée in the schists of Furlund, Belgium. The amphibolite is laminated and made into boudins. The schists are molded around the extremities of the broken layer. An envelope of a letter gives the scale.



B. Amphibolite boudinée in the midst of granitized schist, Porto, Finland. The filling by quartz and feldspar in the interfragmentary spaces and in the zone of contact between schist and amphibolite can be seen.





A and B. Boudinage structure in planar banded chromite ore from the Fairview mine.

crystalline chromite were less mobile than the overlying and underlying layers which probably consisted of both crystalline olivine and liquid olivine, and were relatively mobile. Unfortunately this structure was not seen in place but was only found in ore from the dump, hence its relationships to the structure of the ore deposit cannot be stated.

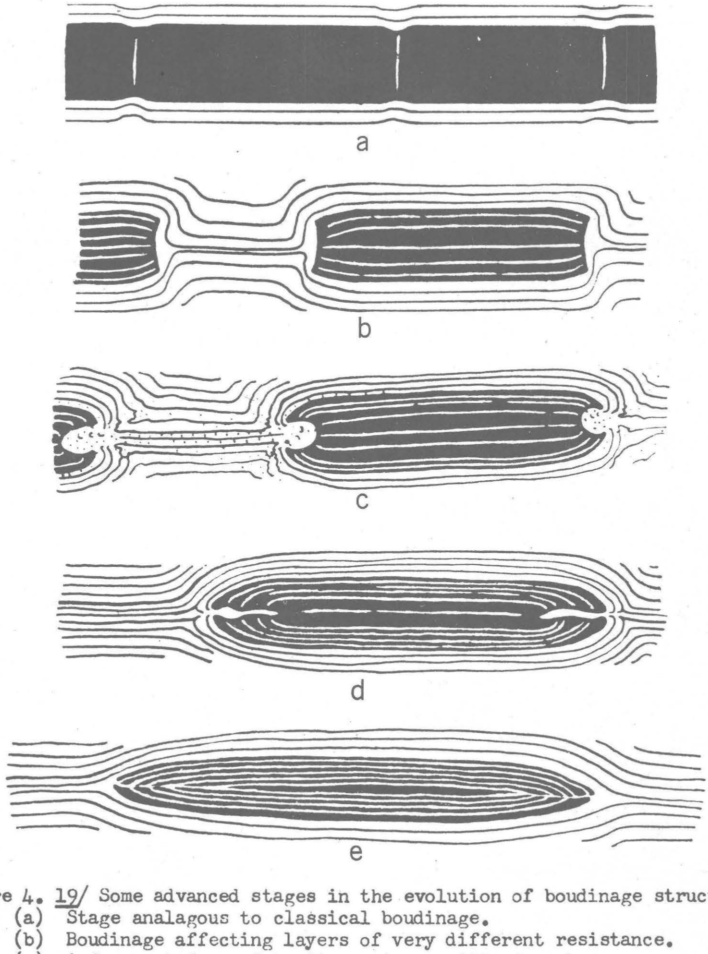


Figure 4. 19/ Some advanced stages in the evolution of boudinage structure:
(a) Stage analagous to classical boudinage.
(b) Boudinage affecting layers of very different resistance.
(c) A frequent form of boudinage in granitized rocks.
(d) The concavities within the ruptured surfaces are nearly filled by layers of the contiguous layers from without the fragment.
(e) End of evolution. Closure of concavity.

19/ Wegmann, C. E., op. cit., fig. 1, 1932.

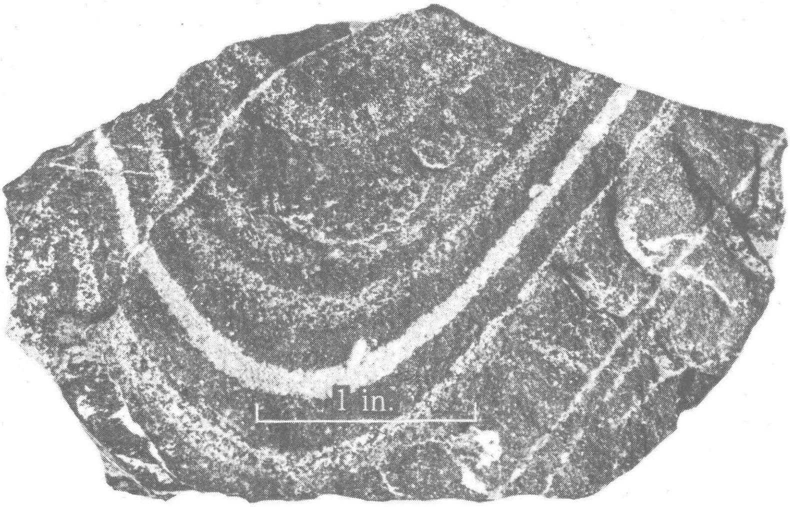
Origin

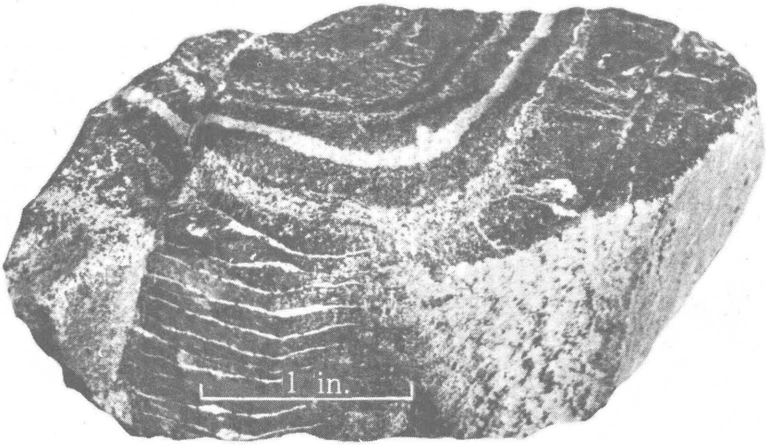
The following theoretical conclusions which bear on the state of the chromite in the peridotite at the time of the intrusion, and the conditions under which the peridotite was intruded, may be deduced from the structures of the chromite just described and the structures of the ultramafic rocks described on pages 29-32. These conclusions may aid in determining the possible size, shape, and distribution of the unexplored ore bodies.

It seems evident from the relationships just described as well as from observations made on other chromite deposits that the chromite was as truly a component of the original peridotite magma as olivine or pyroxene. The chromite appears to have crystallized early from this magma and to have accumulated in certain zones in the melt to form chromite-rich layers and irregular bodies of massive, nodular, and disseminated ore in a more fluid mush of chromite, olivine, and pyroxene crystals and silicate liquids. Crystallization of most of the chromite, much of the olivine, and some of the pyroxene was completed when this crystal-bearing mush moved from its crystallization chamber into its present position. This assemblage was not hot enough nor did it contain sufficient specific heat to recrystallize a selvage as much as a foot thick in the case of silicate wallrocks or tens of feet thick in the case of marble.

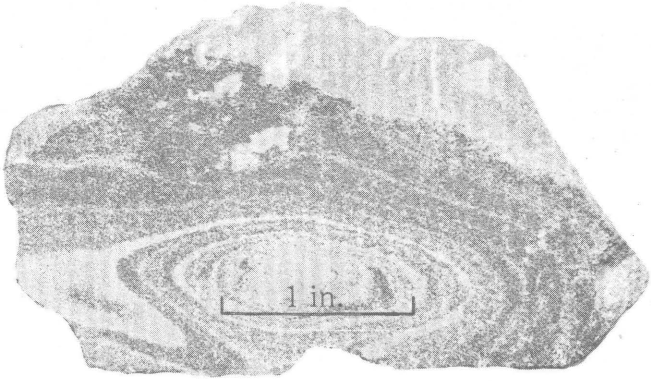
The peridotite mush under pressure behaved like a viscous mass, and the aggregates of chromite tended to move as units of slightly greater rigidity within the larger body. Shearing stresses were set up within the aggregates of chromite either by friction against the enveloping mush or to a greater degree against the walls of the conduit. These stresses effected a stringing out of the aggregates of chromite and possibly caused scattered chromite grains to be alined parallel to the movement In a similar way the spherical nodules, and orbicules were drawn out into ellipsoidal shapes. It seems probable that the drag along the walls of the conduit was not great as the peridotite was intruded relatively rapidly and against negative pressure. The rapidity of the intrusion is indicated by the small thin bodies of peridotite that are found. Such bodies of partly crystallized peridotite magma could not travel far and slowly without congealing. The essentially conformable relations of the intrusives and their localization along unconformities indicate in general that the peridotite did not have the force to break through the formations.

After emplacement and while still plastic the body was compressed parallel to the direction of the flow and folds were formed. That the rock was still plastic is shown by the flowage from limbs to crests of the fold with no evidence of any concommitant fracturing (see pls. 14 and 15). This compression accentuated the lineation of the grains and structures, with the result that masses of the chromite assumed pencil-like form, all in parallel lines, as are the closely packed ellipsoidal nodules and orbicules. Further cooling produced cracking in the completely crystallized chromiferous portions; dunite or saxonite mush penetrated these cracks to form dikes, in places pushing short distances out into the unconsolidated chromite layers, thickening them and diluting the chromite. When the mass was completely solid, cooling produced joints parallel to, and at right angles to the lineation; hydrous minerals formed in these cracks.





FOLD IN PLANAR BANDED CHROMITE ORE FROM THE VETA CHICA CLAIM. A. End view. Note thickening of layers on crest of fold. B. Top view. Note closely spaced serpentine- and magnesite-filled fractures at right angles to axis of fold.



A. Folded chromite ore from the Veta Grande claim. Note that the inner clayers of chromite flowed together after being isolated by a local constriction of the outer layers.

B. Fold in planar banded chromite ore, cut by saxonite dikelet, from the Veta Chica claim. The dark areas in the saxonite are serpentine.

From the preceding discussion it follows that nothing definite is known of the possible size, shape, abundance, and chromite concentration of the original aggregations of chromite. Whatever their original shape, the aggregations would tend to be pulled out parallel to the lineation. This might cause lowering of the concentration of chromite in the original aggregations and pulling out of the aggregations to give separate bodies. The original layers were probably as wide as they were long (the simplest assumption, and there is no evidence to the contrary), and relatively thin. Flowage would tend to shorten the dimensions of the bodies perpendicular to the linearity. Folding parallel to the linearity would do the same; at right angles it would shorten one dimension. In general, therefore, it may be assumed that ore zones and the constituent ore bodies are shaped like a French loaf, many times longer than they are wide, and much thinner than wide. They appear to be banded parallel to the linearity and spotted at right angles to it. As the dominant jointing is parallel to the layering, natural outcrops are apt to give an unduly favorable impression of tonnage and grade.

It seems probable that the chromite had not completely segregated from the silicates before the peridotite masses in this area were intruded; therefore the pod type of deposit, which is characteristic of peridotite masses in which the segregation of chromite was more complete, will not be found in this area.

Mineralogy

Chromite is the only ore mineral of chromium. It is a black, submetallic mineral, brown in finely powdered form or streak, and has a specific gravity ranging from 4.1 to 4.9. Where it exhibits crystal form it occurs as octahedra. The brown streak and small magnetic susceptibility distinguish chromite from magnetite, a mineral of similar color, luster, crystal form, and specific gravity, which is also present in the dunite. Like most of the other spinels, chromite is an isomorphous mixture 20/ of several end members or minerals, in this case magnesio-chromite, $MgO \cdot Cr_2O_3$; spinel, $MgO \cdot Al_2O_3$; magnesio-ferrite, $MgO \cdot Fe_2O_3$; ferro-chromite, $FeO \cdot Cr_2O_3$; hercynite, $FeO \cdot Al_2O_3$; and magnetite, $FeO \cdot Fe_2O_3$. Hence any pure mineral grain of chromite may have one of a large range of compositions and contain chromium, iron, aluminum, and magnesium. To determine the chemical character of any disseminated ore, it is necessary to determine the composition of the carefully concentrated constituent chromite. Accurate sampling is necessary because the fine-grained, disseminated ores often run lower in chromium and higher in iron than lumps of coarse-grained, "high-grade" ore.

The chromium content of chromite is usually stated in percentage of chromic oxide. The richest specimens ever analyzed in the laboratory of the Geological Survey 21/ have in excess of 61 percent Cr_2O_3. The value of chromite depends not only on the chromium content but on the iron content as well, and this is expressed by the chromium-to-iron ratio, which is the quotient of the percentage of chromium divided by the percentage of iron.

20/ Stevens, R. E., Composition of some chromites of the Western Hemisphere: Am. Mineralogist, vol. 29, p. 24, 1944.

21/ Stevens, R. E., op. cit., analysis 45, p. 14, 1944.

Specifications for chromite for metallurgical use usually call for a chromic oxide content of 45 percent and a chromium-to-iron ratio of 3. If the ore is to be used as a refractory, the content of alumina (Al_2O_3) is of importance, and the sum of chromic oxide and aluminum oxide should exceed 60 percent.

The silica content of both metallurgical and chemical ore was limited by specificiation to 5 percent prior to World War II; it is probable that a similar grade will be demanded for postwar purposes. As the silica is present in the gangue minerals only, any beneficiation process must reduce the amount of the gangue mineral to 10 percent.

The gangue mineral, usually associated with chromite is olivine, with small amounts of pyroxene in a few places. The olivine is a high-magnesium olivine and has a specific gravity of from 3.26 to 3.40. Its hardness is about 6.5. The secondary minerals include serpentine formed by the alteration of olivine and pyroxene, a little magnesite, and kämmererite, a purple micaceous mineral that is a chromium-bearing clinochlore. Unusually perfect crystals of this mineral occur on the Octopus or Mary Lou claim (see p.60) and on the Emma Bell claim. It is probably formed by deuteric alteration of chromite and olivine. A very little uvarovite, the deep-green chromium garnet, is occasionally found as a coating of tiny crystals on joint surfaces in ore.

Chemical composition of the chromite

Four complete and six partial analyses have been made of carefully cleaned chromite from this district. They are listed in the following table.

The samples are of various structural types of ore and from different parts of both the Seiad Creek-Red Butte and the Hamburg-McGuffy masses. The chromic oxide content of all the clean mineral is high, ranging from 55.30 to 57.92 percent. The iron content ranges from 14.06 to 20.52 percent; the latter figure is high for most chromite in the Pacific Coast States. As microscopic observation shows little or no alteration of the chromite grains, the iron content is probably an original characteristic of the mineral and not due to the addition of ferric oxide or magnetite to the chromite grains, nor to the substitution of ferric oxide for chromic oxide in the mineral by secondary processes. In general, the lower the chromic oxide content, the higher the iron content, so the lower-grade ores have the lowest chromium-iron ratios. It has been pointed out elsewhere 22/ that the disseminated ore in Siskiyou County consistently has a lower chromium-iron ratio than the pod type of ore, though the chromium oxide content shows no consistent difference. It is interesting to note that the nodular and orbicular ores have a lower chromic oxide and higher iron content than the other types of disseminated ore. The chromium-iron ratio of all the disseminated ore, though better than in many American ores, is still less than the prewar metallurgical requirements, i. e. 3:1.

22/ Wells, F. G., Rynearson, G. A., and Cater, F. W., Jr., Chromite deposits of Siskiyou County, Calif.: In preparation.

Analyses of chromite ores from the deposits near Seiad and McGuffy Creeks

	FGW-39-41 1/	FGW-40-41 1/	FGW-41-41 1/	FGW-42-41 1/	FGW-43-41 1/	FGW-44-41 1/	FGW-45-41 1/	GAR-100-42 2/	GAR-103-42 2/	A 3/
Cr_2O_3	58.58	58.45	55.30	56.73	56.83	54.75	54.18	57.67	58.82	57.92
Al_2O_3	--	9.36	11.51	--	9.27	--	--	--	--	5.84
Fe_2O_3	--	4.47 4/	4.27 4/	--	5.19 4/	--	--	--	--	6.40
FeO	--	14.15 4/	15.58 4/	--	17.19 4/	--	--	--	--	14.83
MgO	--	12.71	12.06	--	10.77	--	--	--	--	13.12
MnO	--	.12	.22	--	.22	--	--	--	--	.25
TiO_2	--	.35	.41	--	.26	--	--	--	--	--
CaO	--	None	.08	--	None	--	--	--	--	.26
SiO_2	--	.22	.32	--	.34	--	--	--	--	1.29
H_2O+	--	.08	.12	--	Trace	--	--	--	--	--
Total		99.89	100.27		100.07					
Sp. gr.	--	4.51	4.51	--	4.68	--	--	--	--	--
Cr	40.10	40.01	37.85	38.82	38.90	37.47	37.08	39.49	40.28	--
Fe	14.75	14.14	15.39	14.32	16.99	18.86	20.52	14.75	14.06	--
Ratio Cr:Fe	2.72	2.83	2.46	2.71	2.29	1.99	1.81	2.68	2.86	2.50
Cr_2O_3 in ore	23.51	41.39	39.90	41.43	17.40	15.42	9.13	36.70	43.37	--
Percent chromite	40	71	72	73	31	28	17	63.6	73.7	--
Impurity	--	Serpentine	Serpentine & Olivine	--	Serpentine	--	--	--	--	--

1/ R. E. Stevens, analyst, U. S. Geological Survey.
2/ M. K. Carron, analyst, U. S. Geological Survey.
3/ Charles Milton, analyst, U. S. Geological Survey.
4/ Calculated to give 1:1 ratio of $RO:R_2O_3$.

FGW-39-41. Specimen from southwest pit on ore zone extending through southern half of Grand Falls claim and northern half of Grand Canyon claim, McGuffy Creek, Siskiyou County, Calif.
FGW-40-41. Specimen from northermost pit of Veta Chica deposit, McGuffy Creek, Siskiyou County, Calif.
FGW-41-41. Specimen of massive chromite from southern end of Cerro Colorado claim, McGuffy Creek, Siskiyou County, Calif.
FGW-42-41. Contorted planar banded ore from northwest pit of Cerro Colorado, McGuffy Creek, Siskiyou County, Calif.
FGW-43-41. Ore showing linear structure from Veta Grande claim, McGuffy Creek, Siskiyou County, Calif.
FGW-44-41. Nodular chromite from Black Spot No. 1 claim north of McGuffy Creek, Siskiyou County, Calif.
FGW-45-41. Orbicular ore from Mary Lou (Octopus) claim, McGuffy Creek, Siskiyou County, Calif.
GAR-100-42. Channel sample cut across upper ore zone at top of cut 5, Fairview mine.
GAR-103-42. Channel sample cut across upper ore zone at south end of cut 7, Fairview mine.
A. Sample collected from the Seiad Creek deposit by W. D. Johnston, Jr.

Reserves

The known reserves of the district total 274,500 short tons of indicated and inferred ore averaging about 8 percent Cr_2O_3, in 6 deposits, three of which are in the Seiad Creek-Red Butte mass, and three of which are in the Hamburg-McGuffy mass. They are listed below in order of importance. Detailed analyses of the reserves of the Seiad Creek and McGuffy Creek deposits are

Reserves estimated May, 1943

Mass	Property	Reserves in short tons		
		Indicated	Inferred	Total
Seiad Creek-Red Butte	Seiad Creek (Mountain View group)	112,000	100,000	212,000
	Emma Bell		2,000	2,000
	Kangaroo Mountain (Anniversary claim)	1,500	4,000	5,500
Hamburg-McGuffy Creek	McGuffy Creek	25,000	25,000	50,000
	Fairview claims	1,500	4,000	5,500
	Ladd (Dolbear)		3,000	3,000

given with the description of these areas (see pp. 51-62).

These estimates were made prior to June 1943, and do not include any ore mined since then. A total of 3,995 long tons of ore that averaged at least 35 percent Cr_2O_3 has been shipped from the district during the period June 1, 1943, to December 31, 1944, but as more ore may have been developed in the process of mining it cannot be assumed that the ore reserves have been lessened by this amount.

These reserves probably include all of the ore that occurs in deposits large enough to make mining feasible, and that lie at the surface or that can be explored by trenching.

Although it is reasonable to assume, on the basis of the present hypothesis of origin and emplacements, that other deposits of similar magnitude and grade exist at depth, it is questionable whether costly methods of deeper exploration are justified with the price of chromite that existed in 1944.

The ore as figured in the reserves averages 8 percent chromic oxide. To obtain ore of this grade it will be necessary to do highly selective mining or to sort the mill feed, or both. It will probably be found that the ore breaks smaller than the enveloping dunite. Other factors that bear on the milling problem should be considered. The concentrate will contain more iron than the pure chromite and hence have a lower chromium-iron ratio. Because of the freshness of the dunite, sliming of the chromite during crushing with consequent losses during gravity concentration are probable. The gravity of the olivine is about 3.5 and of chromite about 4.4 The specific gravities of the chromite and the olivine from a specimen of ore from the Anniversary claim were determined in the laboratory of the Geological Survey. The specific gravity of the chromite with a little adhering olivine was 4.03; the specific gravity of the olivine practically free from chromite was 3.18. This is a small difference for simple gravity separation. The milling characteristics of this ore more closely resemble those of ore from the Stillwater district, Mont., than they resemble the characteristics of the Gray Eagle and Castro mines in California.23/

Many milling tests have been made on the ores from this district. Averill 24/ has published the results of tests made prior to 1935. The Bureau of Mines has reported briefly on tests made in 1938 and 1940.25/ Other tests were made by the Bureau of Mines on ore submitted to them in 1942, but the results have not been published. Flotation tests have been made on this ore by George H. Griswold, Jr., of Butte, Mont. for the Rustless Mining Corp. and by the Southwestern Engineering Co. of Los Angeles for the Kangaroo Mountain Chrome Co. Sink-and-float tests 26/ have been made on the ores and ore has been tried in the Humphreys Spiral Concentrator.27/ Recovery from these tests was less than 75 percent of the chromic oxide content of the heads. The concentrates made by the various methods of beneficiation usually assayed 45 percent of Cr_2O_3, but their chrome-iron ratio was consistently under 2.5.

Chemical beneficiation of ore from the Seiad Creek mine has been investigated by the Bureau of Mines 28/ and the results have been published.

MINES AND PROSPECTS

Seiad Creek-Red Butte mass

Many chromite occurrences have been found in the Seiad Creek-Red Butte mass. Stringers as much as 6 inches wide and 5 feet long crop out on Red Butte and Kangaroo Mountain. Several areas in which chromite schlieren are sufficiently abundant to give a minable width of 2 or 3 percent grade and which contain a few hundred tons each are known to be present above an altitude of 4,500 feet. The Kangaroo Mountain, Emma Bell, and Seiad Creek deposits which are described below are deposits of the type that contain more than 2,000 tons of ore averaging 5 percent of chromic oxide.

23/ Huttl, J. B., California chromite assumes new importance; Eng. and Min. Jour., vol. 143, pp. 43-46, 1942,

24/ Averill, C. V., Mines and mineral resources of Siskiyou County, Calif.: California Jour. Mines and Geology, vol. 31, no. 3, pp. 267-269, 1935.

25/ U. S. Bur. Mines Repts. of Inv. 3370, p. 87, 1938; 3419, p. 41, 1938; 3484, pp. 19-20, 1940.

26/ Butler Brothers, Communication dated May 26, 1943.

27/ Humphreys, Personal communications.

28/ Boericke, F. S., and Banzert, W. M., Effect of variables in chemical beneficiation of chromite ores: U. S. Bur Mines Rept. Inv. 3817, July, 1945.

Kangaroo Mountain deposit (Anniversary claim).

The Kangaroo Mountain deposit or Anniversary claim is located in secs. 13 and 14, T. 47 N., R. 12 W., on the crest of the Siskiyou Mountains at an altitude of 6,100 feet. A Forest Service road climbs 4,700 feet over a distance of 12 miles to within a few thousand feet of the deposit. The exposed location of the deposit makes mining operations difficult during the winter months and the road is apt to be closed by snow from November to May.

The occurrence was discovered by E. W. Kubli in the autumn of 1918 but was left unclaimed until 1941 when he and his sister, Mrs. L. M. Scott, staked the Anniversary claim and three others. During the same year Philip S. Davies and George W. Malone took a lease on the group and initiated operations which were continued into 1942. A Geological Survey field party under John S. Livermore and comprising P. W. Richards, D. A. Phoenix, and Fred W. Gros, mapped the area in October 1941.

The deposit is in the bare peridotite ledge that forms the west wall of a northward-draining glacial cirque (see pl. 16). Small lakes and scattered remnants of moraines occupy the lower slopes and floor of the cirque. Gneissic diorite, quartzite, and marble are exposed at the head of the cirque. They are flanked to the east and west by partially serpentinized peridotite. Although in detail the distribution of these rocks is complex, they appear to form the west limb of a northward-plunging anticline and the peridotite lies above them. Some metamorphism has been produced by the peridotites both within itself and within the invaded rock (see p. 29).

The ore is located about 100 feet above the contact (see pl. 17). Here the peridotite is a medium-grained dunite and its slightly greater alteration is shown by the greenish tinge on weathered surfaces. The chromite occurs in a zone that lies rudely parallel to the contact with a north-south strike and a dip about 60° W. The nature of the cliff exposure is shown in figure 5. Its maximum length is 180 feet and it is 40 feet thick

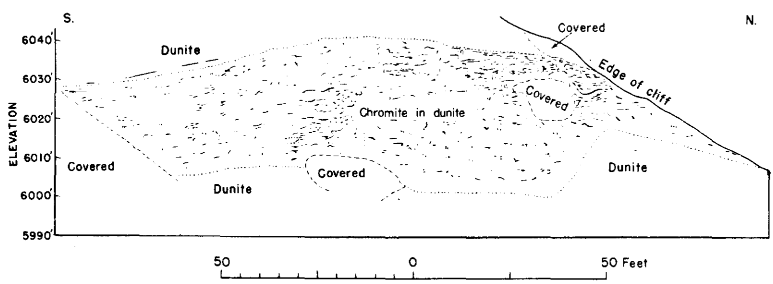


Figure 5.—Vertical projection of the Anniversary ore zone parallel to cirque wall

The ore consists of grains of chromite as much as 2 millimeters in size scattered singly or in small bunches or wisps through the dunite. The concentration of these grains varies from place to place and is shown diagramatically in figure 5; where most abundant they may comprise 50 percent of the mass by volume, but throughout most of the zone they do not make up more than 10 percent and in places about 5 percent.

Assuming 10 cubic feet per short ton of ore, the deposit contains 525 short tons of ore for each foot down the dip as far as the cross section remains the same. This is indicated for a distance of 3 feet down the dip and it may be inferred for an over-all distance of 10 feet, making a total of 5,250 short tons of indicated and inferred ore. The grade is difficult to estimate but would probably not average better than 5 percent Cr_2O_3.

At the bottom of the ledge below the outcrop there is some chromite-bearing talus. Possibly as much as 250 short tons of ore might be recovered from this talus slope at a reasonable cost.

No analysis of pure chromite from the ore is available but a high chromic oxide content seems likely (see pp. 40-41). Probably a satisfactory concentration could be made although the recovery might be low. Water for milling is available about 2,000 feet downstream from the deposit. Some bunches of pure chromite containing as much as 1 or 2 tons have been seen on Red Butte and Kangaroo Mountain, but they do not merit individual description.

Emma Bell prospect

The Emma Bell prospect, sometimes called the Stanton property after its owner, Mrs. W. P. Stanton, was leased to Development Corporation of Delaware in 1942. The property consists of 5 claims held by location (see pl. 18). They are in sec. 7, T. 47 N., R. 11 W., and extend across the Forest Service road that leads from the Forks of Seiad Creek to Kangaroo Mountain (see pl. 6). The claims are in a draw formed by a tributary of the West Fork of Seiad Creek and extend from the crest of the ridge at 6,000 feet above sea level to about 4,000 feet. At the time the claims were examined very little exploration work had been done but the terrain is very steep and the almost bare rocks furnish excellent exposures.

The rock is largely dunite and the ore zone lies about midway between the upper and lower contacts of the peridotite mass. Schlieren of dense or disseminated chromite are found at intervals over a distance of 3,500 feet and along a strip that trends N. 20° W. parallel to the eastern contact of the peridotite. In places in this strip schlieren are abundant enough to form an almost continuous zone. The most important of these extends from the road down a gully a vertical distance of nearly 600 feet and a horizontal distance of 800 feet. It is about 200 feet wide and consists of very low grade rock if taken as a whole. Typically the chromite occurs as high-grade stringers many of which are much folded and drag-folded. They are from a quarter of an inch to 1 inch wide and from 1 to 3 feet long. The largest stringer seen was 6 inches thick, 3 feet long and was surrounded by barren dunite. The stringers are spaced at intervals of 15 to 30 feet both along and across the strike.

At some places 4 or 5 narrow schlieren occur in an area 3 to 5 feet wide separated from the next group by 20 feet or more of barren dunite. Such groups average as much as 50 percent chromite but as each group contains only 5 or 10 short tons of milling ore and as the groups are widely spaced, little of it can be considered to be ore.

A zone 1 to 3 feet thick, consisting of stringers of massive chromite and of layers of fine-grained disseminated chromite, is exposed for a strike length of 350 feet at the southern end of the Emma Bell No. 1 claim. The exposed depth is about 75 feet and the linear elements in the ore indicate a horizontal attitude for the long axis of the ore body. It is estimated that about one third of this material will contain about 25 percent of chromic oxide by volume.

Another ore zone is exposed at the southern end of the Emma Bell No. 2 claim. The zone is 1 to 5 feet thick and is exposed for 100 feet more or less along the strike with a thickness of about 50 feet. The ore is of somewhat better grade and is similar in appearance and attitude to that described in the preceding paragraph. Scattered outcrops of ore between the two showings suggest that they may be part of a continuous zone.

Just south of the south end of the Emma Bell No. 2 claim and parallel to the main zone there are several layers of high-grade chromite forming a deposit 2 to 10 feet thick. The individual layers are a quarter of a foot to 1 foot in thickness and make up one fourth to one half the thickness of this deposit, which is exposed for a length of about 80 feet and a depth of 25 feet. The ore could be sorted to a product containing 45 to 50 percent of Cr_2O_3.

Probably 200 short tons of ore containing 40 to 45 percent chromic oxide could be sorted from 2,000 short tons of the mined product. The rejected material would be a low-grade mill feed. The chromite from these claims is believed to be similar to that from other deposits in the district (see pp. 40-41).

Blue Eagle and Black Eagle claims

Two claims, the Blue Eagle and the Black Eagle, located close to the east section line of the SE¼ sec. 7, T. 47 N., R. 11 W., at an altitude of about 5,000 feet, are described by Allen.29/ These are near the Emma Bell claims and may form part of the property now held by Mrs. W. P. Stanton, but it has not been possible to decide this matter. Allen's description follows:

> "Blue Eagle Claim is located just west of the main ridge which runs down to the Seiad mine. The country rock is a porphyritic peridotite except within 200 feet of the deposit, where it becomes equigranular and fine-grained, probably changing to dunite.
>
> The orebody strikes N. 10-20° W. and dips 45° E. It outcrops for 20 feet, being 5 inches wide at the top (north), widening to 5 feet or over in the northern 10 feet, and then narrowing to about 2 feet at the southern end. It occurs as a fat lens which pinches out quickly at both ends.

29/ Allen, John E., Geological investigation of chromite deposits in California: California Jour. Mines and Geology vol. 37, no. 1, pp. 101-167, 1941.

The ore is both disseminated and banded, containing considerable gangue. A chip sample taken across and along the exposed face of the lens assayed 24.56 percent chromic oxide. Small float appears 200 yards to the west.

Black Eagle claim lies a quarter of a mile to the S. 70° W. of the Blue Eagle claim and at about 100 feet lower elevation, near the bottom of a steep gully. Near the deposit peridotite banding due to orientation of diallage crystals is prominent, and strikes N. 45° W., dipping 70° S.

The banded ore in this cut (and less distinctly elsewhere) consists of alternating layers of high-grade chromite (assaying 54.79 percent chromic oxide), and chromiferous dunite. A section across the entire zone consists of about 30 percent bands of 50 percent chromite, and 70 percent gangue of perhaps 10 percent chromite. Although the boundaries of the bands appear to be sharp, they actually do show some gradation upon close examination, and the gangue material has about 10 percent chromite crystals. The high-grade ore is associated with kammererite, in small interstitial grains and large bundles of plates (up to 15 millimeters in diameter) in cavities. The bands vary in size. Usually they occur in pairs, with a thicker (1- to 3- inch) band above a thin band (¼-½ inch), separated by about 1/2-3/4 inch of gangue. Some of the bands are not continuous throughout the outcrop, but from shorter lenses.

The country rock to the east and below this deposit shows numerous 'splatters' and fine dissemination of chromite." See figure 6.

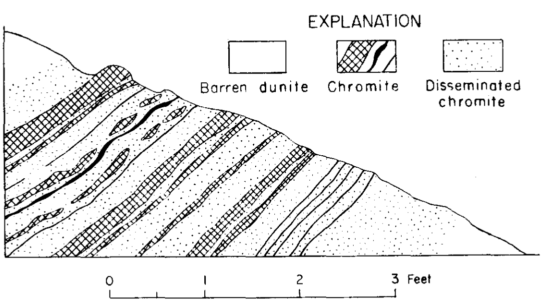


Figure 6.—Cross section of ore body, Black Eagle claim north of Seiad.

Seiad Creek mine

Introduction.—The Seiad Creek mine property includes most of sec. 20, T. 47 N., R. 11 W., between the East Fork and West Fork of Seiad Creek (see pl. 19). It is 7 miles by all-weather road from Seiad Valley. Seiad Creek carries a good flow of water the year round and neighboring slopes are well timbered. This property was discovered and worked during World War I. It was then called the Reddy Chrome mine or Seiad mine, and consisted of four claims held by Davis Brothers and Crawford; four claims held by Johnson and Wescott; three claims held by Phillips, Reddy, and Crawford; and five claims held by Straszk and Reddy. All these claims were leased and operated by Dr. J. F. Reddy. According to an auditor's report 704 long tons of ore were shipped from the property between May 16 and October 23, 1918. Of this, 261 long tons were shipped by Reddy, 103 long tons were shipped by Dozier, and 340 long tons of broken ore were stock piled at the mine. After the war the Reddy interests relocated several claims and held them until 1933 when H. W. Gould of San Francisco located four claims. The Reddy and Gould interests held the deposits in litigation until 1938, when Rustless Mining Corp. bought out the litigants. In 1943 the Rustless Mining Corp. leased the 16 claims they then held by location to the Kangaroo Mountain Chrome Co., Mr. Philip S. Davies, President. This corporation mined and shipped 2,060 long tons of hand-cobbed ore during 1943 and 1944.

The U. S. Bureau of Mines explored and sampled the deposits by trenching, diamond drilling, and underground work from April to October 1941, as part of the strategic minerals investigations program. Mr. Frank J. Weibelt was engineer in charge and Clay T. Smith of the Geological Survey gave geologic supervision from April 15 to October 12, 1941.

Geology.—The deposits crop out on the nose and western slope of the steep spur between the forks of Seiad Creek and are near the middle of the sill-like mass of ultramafic rock. The mass is flanked on the east by schists in faulted contact. A short distance west of the mine gneissic quartz diorite is interlayered with the ultramafic rock in lit-par-lit structure totaling 500 feet in thickness. Foliation is also prominent in the dunite and is best developed near the contacts.

In these claims the ultramafic mass is a medium-grained dunite consisting of over 95 percent of olivine and a small proportion of enstatite. Though the dunite is partially serpentinized, usually 75 to 90 percent of the rock is unaltered It is cut by small sills and dikes of hornblendite. As these are more resistant to weathering than the dunite, they tend to stand out as narrow ribs or ridges usually only 2 or 3 inches wide. Tremolite, talc, magnesite (?), anthophyllite, and chlorite occur as products of metamorphism and hydrothermal alteration.

Ore.—Chromite, and magnetite which may be confused with it, are for the most part accessory minerals. Accessory chromite is usually fine-grained, less than 1 millimeter, and is sparsely scattered through the dunite. The ore is of three types—massive, streaked, and disseminated.

Streaked ore is the most abundant. It consists of pencil-shaped masses of chromite grains which form linear elements in the dunite. Where the pencil-shaped masses are numerous, they constitute tabular zones and the rock is banded. The streaks seldom exceed a quarter of an inch in width and are usually only a few feet in length. Individaul streaks or bands taper in each direction, usually ending where a similar concentration a few inches to one side displays its maximum width. With increase in concentration, size, and abundance, the streaks merge into homogeneous chromite—called massive ore—but even then the linear structures are recognizable as pencil-shaped masses and faint bands of olivine grains. In the massive ore chromite grains tend to be larger than in disseminated ore and may be as much as 2 millimeters in largest dimension. They have also a higher chromium-iron ratio.

Disseminated chromite usually occurs as halos around the ore bodies whose boundaries are therefore indefinite.

A very little uvarovite and kämmererite was seen on these claims.

The grade of any mineralized zone as determined by sampling across the width ranges from 1 to 2 percent Cr_2O_3 to over 15 percent Cr_2O_3, but total widths that yield more than 6 percent material are scarce. Most of the exposed streaks of chromite within the ore bodies which could produce shipping ore averaging better than 48 percent Cr_2O_3 were removed during mining operations prior to 1945.

Localization of chromite.—The ore on the Mountain View claims is found about midway between the walls of the dunite body, but there is no correlation between the distribution or size of individual ore bodies and their distance from the contacts.

Roughly the deposits may be likened to a large cigar elongated N. 50° W., and plunging at about 10° SE. The over-all length is about 1,300 feet. The ore bodies consist of three zones of chromite-bearing rock which parallel the foliation in the dunite (see pl. 20). This parallelism is probably the accidental result of offsets by numerous small cross faults displacing successive westerly blocks to the north. Originally the deposits probably consisted of three or four ore bodies in a tabular zone. Due to complex faulting these ore bodies have been sliced into numerous small wedges (see pl. 21) which will be difficult to mine.

Faults and joints.—A complex pattern of faults, none of which appears to have any considerable displacement, is exposed in the underground workings in the deposits. Crush zones penetrated by drill holes show that these fractures are widespread throughout the ore zone. The fault pattern is illustrated on plate 21 which is a hypothetical drawing based on rational extrapolations of mapped features that are shown on plates 20, 22, 23.

Three distinct sets of faults have been recognized. No displacements greater than 200 feet are known to occur on any of them and the average displacement on all faults is probably between 10 and 50 feet. The oldest faults are normal faults striking from N. 25° W. to N. 70° W., and dipping about 30° N. Displacements along this set of faults range from 20 to 60 feet and average about 40 feet. Closely associated with the 30°

faults are later normal faults with the same strike but dipping about 45° N. These 45° faults are the most important and also the most abundant. Their displacements range from 20 to 90 feet, but average about 30 feet. These two sets of normal faults cut the ore bodies and cause thickening and repetition; they steepen the dip of the ore zone, and sometimes reverse the dip.

A series of steeply dipping cross faults is later than the normal faults, offsetting them, generally with the west side to the north. Some of these cross faults are reverse in movement, some normal; all strike from 25° to 35° east of north. The displacements are very small; they never exceed 25 feet and average around 10 feet.

Finally, there is a large fault which cuts off the surface exposures of the ore between drill holes J and E (pl. 20); this fault will hereafter be referred to as the West End fault. It is a reverse fault with sufficient strike-slip displacement to mask the reverse character of its movement. It strikes about N. 75° E., and dips 45° N. The total displacement is approximately 95 feet, and the ore zone is offset to the south about 50 feet at the level of the west adit. One of the cross faults appears to be cut off by the West End fault, which, for this reason, is thought to be the latest of the faults or at least to have had the most recent movement.

Workings.—In October 1942, development consisted of the East adit, the West adit, 55 trenches, and 30 diamond drill holes (see pl. 20).

The East adit (see pl. 22) is located on the nose of the ridge. Its portal is at an elevation of 3,210 feet. The workings consist of a tunnel 240 feet long that follows the strike of the ore, and 3 pairs of crosscuts that explored the ore for about 50 feet to both the north and the south. The other features of the workings and distribution of the ore are shown in plate 22. A series of samples taken across the ore assayed as follows:

Analyses of chromite from Seiad mine
K. J. Murata, analyst

Chip samples across the strike of chromite-rich bands of approximately minable grade. Samples taken by C. T. Smith and G. A. Rynearson, August 1938.

Sample No.	Ore minerals in total sample (percent by weight)	Cr_2O_3 in concentrate (percent by weight)
CS-4	16.9	52.35
CS-5a	22.0	51.75
CS-6	17.9	51.22
CS-7	62.7	53.67
CS-9	64.1	50.47
CS-10	28.9	53.09
CS-16	21.4	53.33
CS-17	43.3	52.11
CS-18	64.2	53.32

The magnetite content of CS-4 and CS-5a made up 4.6 and 1.7 percent, respectively, of the concentrate. Though not determined for the others it is believed not to exceed 5 percent.

The West adit is located 1,000 feet to the northwest and 90 feet higher on the west slope of the ridge (see pl. 23). It consists of an adit 130 feet long which crosscuts the ore zone. Drifts have been driven to the north and south 35 feet from the portal. The northern drift follows the ore zone for 40 feet. Here the ore feathers out and the tunnel was driven to the east across the structure for 25 feet without exposing more ore. The south drift explores the ore along the strike for 230 feet. The tunnel turns west at this point and crosscuts the structure for 90 feet. Other crosscuts explored the ore across the structure at intervals of about 75 feet.

The nature of the ore exposed is shown on the map. Branching, longitudinal, and cross faults are well exposed in these workings.

Fifty-five trenches and 30 diamond-drill holes have explored the ore zone for an average width of 400 feet and an over-all length of 1,260 feet, starting at the East adit and extending 300 feet beyond the West adit. They lie between altitudes 3,500 feet and 3,100 feet; one diamond-drill hole penetrated to altitude 2,950 feet. The distribution of these is shown on plate 20. This block of ground appears to have been well explored.

Ore bodies.—The results of the drilling and exploration program completed by the Geological Survey and the Bureau of Mines indicate four and possibly five ore bodies, averaging 6 percent or more Cr_2O_3.

The No. 1 ore body extends from the portal of the East adit to drill profile C (pl. 20). It is bottomed at the east end between 50 and 100 feet below the level of the East adit; its upper limit on the west, as shown by surface exposures above drill holes 9 and 13 and by drill hole B (pl. 20), is about 100 feet above the level of the East adit. This body may extend to the West End fault at levels below those reached by drill holes D, E, and K, but probably will not attain depths much greater than now reached in drill hole C (pl. 20).

The No. 2 ore body lies between the West End fault and drill hole 20 (pl. 20). It is truncated at the surface in its richest part, and is bottomed by the west drift.

The No. 3 ore body is confined to a small area around drill holes 22, 23, and 28, and has not yet been bottomed, but chances of additional ore at depth are slight.

The No. 4 ore body offers most promise for additional ore. It extends between profiles 24 and 25 and from them to drill holes 26 and 30 and may extend as much as 250 feet beyond. This ore body is not bottomed, and might contain as much tonnage as the No. 1 ore body.

No. 5 ore body is of unknown size. It is thought to extend from trench 47 to the extension of the West End fault and be bottomed by drill holes E, D, and B. The extension in depth of the good ore exposed on surface is open to question.

Reserves.—The Seiad Creek chromite deposit at the end of 1941 contained 266,000 short tons of indicated ore averaging 6 percent or more of Cr_2O_3, distributed approximately as follows:

820600 O - 49 - 4

No. 1 ore body	150,000	short tons
No. 2 ore body	65,500	" "
No. 3 ore body	24,500	" "
No. 4 ore body	26,000	" "

About 60,000 short tons of ore based on an 8 percent cut-off value and a grade of 15 percent are indicated. The addition of ore body No. 5 and the possible extensions of the first four ore bodies, plus an additional 25 feet of depth where the ore bodies are not bottomed, increases the tonnage of inferred ore averaging 6 percent or more Cr_2O_3 to 415,600 long tons of ore.

From the five ore bodies nearly 400,000 short tons of indicated ore averaging 4 percent Cr_2O_3 or better could be obtained, and inferred tonnage of this grade might approximate 750,000 long tons.

The only hope for additional tonnages of milling-grade material from the Seiad Creek deposit lies in successful prospecting along the strike of the ore zone. Though additional ore is probably present down the plunge, it probably lies too deep for economic mining.

Hamburg-McGuffy Creek Mass

Five areas in which concentrations of chromite were sufficiently large to merit prospecting have been found in the Hamburg-McGuffy Creek mass. Named from north to south they are: the Ladd, the Fairview, an unnamed claim, the Black Spot, and the McGuffy Creek area. Ore has been shipped from all but the Black Spot area. Reserves at the end of 1941 were 58,500 short tons of indicated and inferred ore (see pp. 53, 55, 62).

The Ladd mine

The Ladd Mine, called the Dolbear or Klamath Chrome mine during World War I, is in secs. 16 and 21, T. 46 N., R. 11 W., on the steep north bank of the Klamath River 600 feet above the stream. It is reached by 3 miles of dirt road from the gravel road at the north end of the bridge across Klamath River (see pl. 6).

The property is owned by John Ladd of Seiad Valley and is leased to Mrs. D. R. Moroney of Hamburg, Calif. During 1942 and 1943 the property was subleased and operated by Ronald Knudsen and then by James K. Remsen. Up to the end of 1943 it had yielded 1,885 long tons of ore, of which 1,598 long tons were mined in 1918.

The mine is developed by 16 open cuts and 4 short adits (see pl. 24). Four disconnected ore bodies are exposed in the workings, and another has been prospected by two small cuts about 500 feet southwest of the glory hole.

The ore body exposed in the upper cuts has the form of a flat lens. In the middle the ore comprises irregular stringers, indistinct bands and high-grade disseminations; toward the margins of the lens it occurs in disseminated clusters and thin massive layers. The ore body dips steeply to the west at the north end and steeply to the east at the south end. It is offset by a low-angle fault with a throw of about 40 feet. The ore has a maximum thickness of 15 feet but averages about 10 feet; the ratio of shipping ore to concentrating ore is estimated at 1:2. If the length is 60 feet, the average thickness 10 feet, and the maximum depth 85 feet, the ore body contains about 765 tons of shipping ore and 1,785 tons of concentrating ore. If the ore body extends another 40 feet beneath the fault at the north end, it may contain 1,050 tons of shipping ore and 2,450 tons of concentrating ore.

A similar ore body exposed in the lower cuts has an average thickness of about 3 feet. It is cut off by a low-angle fault at the north end but may be represented by a small amount of ore exposed in the next cut northeast. If it is 90 feet long, and extends to a maximum depth of 60 feet, the ore body contains about 650 tons of shipping ore and 700 tons of concentrating ore. It may extend another 30 feet northward beneath the fault, in which case the reserves would be 800 tons of shipping ore and 1,000 tons of concentrating ore.

The glory hole is badly caved. Although a little ore is exposed in its walls, most of its ore seems to have been taken out. The ore body in the east cuts also has been mined out except for a few small masses of high-grade chromite.

Fairview mine (Hamburg Bar mine)

The Fairview property comprises 4 claims (see pl. 25) owned by F. S. Pollak of Washington, D. C., and an adjacent claim owned by Hollis Anderson of Scott Bar, Calif. They are in secs. 27 and 34, T. 46 N., R. 11 W., on top of the north-trending ridge which rises steeply from the south bank of the Klamath River. The mine can be reached over 3 miles of very steep dirt road from a point on the gravelled county road 46 miles west of Yreka (see. fig. 2).

The property was operated during World War I by Dr. J. F. Reddy. It was called the Hamburg mine and consisted of the Good Pasture, the Hamburg, the McGinnis, and Red Cap claims. According to an auditor's report 509 long tons of ore were mined, of which 216.29 long tons were shipped. From 1942 through 1944 the property was operated by Harold Ellicksen for F. S. Pollak. He mined and shipped 2,043 long tons of ore.

The deposit is located midway between the eastern and western contacts of the ultramafic body. The ore is in a fresh, dark-green dunite showing practically no serpentine in hand specimens. It is cut by pyroxene dikelets and a large mass of pyroxenite is exposed several hundred feet to the west.

When mapped in the spring of 1942, development consisted of 13 open cuts in ore (see pl. 26). Chromite in layers, in irregular stringers, and in disseminated grains is concentrated in two major zones that are parallel to the foliation of the dunite. Both structures strike N. 30° W. and dip 35°-70° S. The layers of chromite range in thickness from a fraction of an inch to nearly a foot. Some of them are remarkably regular and persistent for as far as 10 or 15 feet. In some places they grade imperceptibly into rock with evenly disseminated grains of chromite. The layers are contorted here and there, forming both large and small folds, and some of the ore shows boudinage structure (see pp. 36-37).

The largest concentrations of chromite are exposed in cuts 5, 6, and 7, near the common corner of the four Fairview claims. In these cuts the two ore zones are 1 to 5 feet thick and are separated by 3 to 25 feet of waste. An ill-defined zone of brecciation suggests that the zone in cuts 6 and 7 is the offset continuation of the zone in cut 5, but it may belong to a different body (pl. 26).

Ore exposed in cuts 2, 3, and 4 and in several intervening outcrops may also represent a continuation of the zones in cut 5, which it resembles in appearance and attitude. Cuts 11, 12, and 13 seem to be mostly mined out, but their location suggests that they may be in a southward contimuation of the two major zones. Considerable trenching would be needed to show whether the zones are continuous.

The following grab samples, taken from channels across the strike of the ore zones, indicate that "low-grade A" 30/ ore can be mined from cuts 5, 6, and 7. Some hand sorting will be necessary, and the ratio of shipping ore to concentrating ore will probably be about 2:1. The ratio for other parts of the property may be about 1:1.

Channel number	Open cut	Cr_2O_3 (percent)	Thickness of ore (feet)
1	7	31.18	1.2
2	7	44.50	1.5
3	7	37.01	2.0
4	6	39.32	3.0
5	5	41.63	2.5
6	5	38.12	2.0
7	5	40.71	3.0
8	4	31.46	1.2

The chromite shipped has ranged in composition from 28.14 to 42.78 percent Cr_2O_3; from 10.10 to 12.09 percent Fe; and from 2.14 to 2.49 in chromium-iron ratio. Two samples of ore, G A R -100-42, from across the upper ore zone at the top of cut 5, and G A R -103-42, from across the upper ore zone at the south end of cut 7, were analyzed in the laboratory of the Geological Survey.

30/ Low-grade A as defined by the Metals Reserve Company February 20, 1942, must meet the following specifications:

Chrome(Cr_2O_3)	Minimum	40.0 percent
Silica	Maximum	13.0 percent
Phosphorus	Maximum	0.50 percent
Sulphur	Maximum	1.00 percent
Chrome (Cr):Iron(Fe) Ratio	Minimum	2.0:1

Analyses of chromite from the Fairview mine
(R. E. Stevens, Analyst)

Concentrates of chromite					Ore					
Sample	Cr	Fe	Ratio Cr:Fe	Cr_2O_3	Cr	Fe	Cr:Fe	Cr_2O_3	Percent Chromite	SiO_2
GAR-100-42	39.49	14.75	2.68	57.67	25.68	11.58	2.18	36.70	63.6	14.08
GAR-103-43	40.28	14.06	2.86	58.82	29.68	11.81	2.51	43.37	73.0	10.02

The following estimates of reserves were made in the spring of 1942. About 1,400 long tons of hand-sorted ore were mined during 1943 and 1944. In estimating reserves an ore factor of 10, and a factor of ½ to compensate for topography, have been entered in all of the calculations. On the assumption that the ore zones in cut 5 have a length of 75 feet, an average aggregate thickness of 4 feet, and a maximum depth down the dip of 50 feet, it is estimated that they contain 500 tons of shipping ore and 250 tons of concentrating ore. The ore zones in cuts 6 and 7 contain about 800 tons of shipping ore and 400 tons of concentrating ore, if they are assumed to be 80 feet long, 4 feet in average aggregate thickness, and 75 feet in maximum depth. If the zones are continuous between cut 4 and cuts 6 and 7, they would have a length of 250 feet; an average aggregate thickness of 3 feet and a maximum depth down the dip of 120 feet can be inferred. Such an ore body might yield 3,000 tons of shipping ore and 1,500 tons of concentrating ore. If the zones are continuous from cut 2 to cuts 6 and 7, the reserves may amount to as much as 8,000 tons of shipping ore and 8,000 tons of concentrating ore.

During the period 1942 to 1944, 2,042 long tons of hand-sorted ore were mined and shipped from the property. Present reserves are not known because mining may have developed new ore not included in the above estimates which would necessitate a change in the figure obtained by subtracting the production since 1942 from the above reserves.

McGuffy Creek area

Introduction.—The McGuffy Creek area includes all the chromite deposits present on the south slope of McGuffy Creek, sec. 30, T. 45 N., R. 10 W., and sec. 25, T. 45 N., R. 11 W. McGuffy Creek is a short southward-flowing tributary of the Scott River and joins the Scott River about 5 miles above the confluence of this stream with the Klamath River (see pl. 6). The creek has a good flow of water throughout the year. It occupies a canyon the sides of which are steep and largely composed of bare rock slopes and ledges. The deposits are between 3,250 feet and 4,850 feet above sea level. A steep truck trail leads from the road in the valley up to the lowest claim, the Lady Gray.

Nine claims were held in the area when it was mapped in 1941. They were the Cerro Colorado, the Veta Chica, the Mil Diablos, Veta Grande, Piedras, and Mary Lou claims held by the H. W. Gould Co., and under lease to the Rustless Mining Corp., and the Grand Canyon, Grand Falls, and the Bluestone claims held by

Mrs. D. R. Moroney (see pl. 27). Since 1941 Mrs. Moroney has staked the Lady Gray claim, adjoining the Piedras claim on the east.

Considerable development work was done on the various claims during World War I and ore was shipped from what are now the Veta Grande and Mary Lou claims—then named the Red Butte and Octopus—by Milne and Reichman. Hand-sorted ore was sledded by teams of horses down to the Scott River road and trucked from there to Yreka via Fort Jones (see fig. 2). Total shipments from the two claims amounted to 509 long tons. A few years ago the Cerro Colorado, Veta Chica, Mil Diablos, Veta Grande, and Piedras were located by the H. W. Gould Co. of San Francisco, and leased to the Rustless Mining Corp. in 1939. Little more than assessment work was done on these claims until the summer of 1941 when the Bureau of Mines trenched and sampled the Veta Chica and Cerro Colorado. A party headed by John S. Livermore mapped the area geologically at this time. In the spring of 1942 the Bureau diamond drilled these claims. The geological aspects of the drilling program were supervised by G. A. Rynearson of the Geological Survey. Results of the Bureau of Mines' work have been made available to the writers, but though these data have been very helpful, the figures of reserves (see pp. 59, 60, 62) have been estimated independently.

In 1944, 44.85 long tons of hand-sorted ore were shipped from the Lady Gray claim by A. W. Diggle.

Geology.—The McGuffy Creek deposits occur in the southern end and on the top side of the tabular Hamburg-McGuffy Creek mass. Here the mass is about 2 miles wide and dips steeply to the southwest. It shows a rude layering of two rock types that differ in the relative abundance of pyroxenes. An upper and a lower layer, each containing more than 5 percent pyroxene (saxonite or lherzolite) are separated by a median layer of dunite containing no pyroxene (see pl. 27). From 30 to 50 percent of the dunite has been serpentinized, whereas only 5 to 20 percent of the saxonite and lherzolite have been. The incipient foliation and jointing of the peridotite and the elongation of the chromite bodies are both parallel to the contact, as is also the gneissic structure of the contiguous diorite. Both rocks are cut by small bodies of pegmatite containing black tourmaline and actinolite besides the normal constituents (see p.25). On the Mil Diablos claim a fissure containing graphite parallels the same structure. The dunite, lherzolite, and chromite are cut by later dikelets of pyroxene-rich saxonite (see pl. 15B) ranging in width from a fraction of an inch up to about 1½ feet. These dikelets consist chiefly of olivine but also contain appreciable amounts of enstatite; locally the rock becomes almost a pyroxenite. The olivine and pyroxene have been only very slightly altered to serpentine (0 to 20 percent).

Structure.—The peridotite is characterized by two systems of joints. The dominant system cuts the rock into a great number of many-sided prisms the edges of which trend N. 10° to 30° W., with a 5° to 20° plunge toward the north. The parallelism of these edges gives the rock a linear element. The other joints cut the prisms perpendicular to their length (see pp. 31-32).

East-west faults have been recognized in the area. They are usually indicated by small displacements of the chromite structures and in general are not shown on the maps. Two east-west faults of considerable displacement are shown on plate 27.

Though the displacements cannot be determined, they are to be measured in tens if not hundreds of feet. The apparent relative displacement of all observed faults is south block east.

Small open flexures of the thin layers of chromite are common. Some of these are more closely flexed and resemble poorly developed drag folds. One such fold of larger dimensions is exposed on the Veta Colorado claim. The axes of these folds parallel the linear elements indicated by the joint system. Such folds can be detected only where indicated by layered chromite and probably many more unrevealed folds of this type exist in the chromite-free peridotite.

The linear element indicated by the first-described joint system, as well as by the folds, is emphasized by the parallelism to this element of the rods of chromite and the major axes of ellipsoidal nodules and orbicules of chromite (see p.32). This linearity is the most important structural element in the peridotite mass, at least in the area mapped. As previously stated, it strikes N. 10° to 30° W. with a 5° to 20° plunge toward the north.

Ore.—The chemical composition of the ore in the McGuffy Creek area is similar to the composition of the chromites throughout the district and is discussed on pages 40-41. It is interesting to note that the nodular and orbicular ores of chromite have a lower chromic oxide and a larger iron content than the other types of ore. Euhedral chromite crystals are rare in these deposits and in most of the ore the chromite grains are irregular or rounded and are about 1 millimeter in diameter. Kämmererite and a very little uvarovite are present. Kämmererite is a purple micaceous mineral, a chromiumclinochlore. Unusually perfect crystals of this mineral occur here.

Chromite grains are concentrated to form 5 more-or-less distinct structural varieties of ore: massive, disseminated, planar banded, linear banded, and orbicular (see pp. 34-37).

In massive and disseminated ore there is no apparent arrangement of the grains and all possible gradations from a few scattered grains in dunite to aggregates of pure massive chromite are found. Neither type is very common in the area.

Banding is developed to some degree in nearly all the exposures. Planar banding or interlayering of high- and low-grade ore is best shown on the Veta Chica claim where layers of almost solid chromite, usually an inch or less thick, alternate with layers of partially serpentinized dunite containing a few scattered grains of chromite. Commonly a group of closely spaced layers is separated from a similar group by a few feet of barren rock (see p. 35). The bands are of variable width and continuity. Layers of massive chromite as much as 8 inches thick have been observed and narrow layers can be traced along the strike for 30 feet or more before they grade into dunite or are sharply terminated. Exposures are such that it has been impossible to follow individual layers more than 15 feet down the dip; it is believed that they are not as continuous in this direction as along the strike. As seen by the unaided eye the contacts of the layers are sharp and straight, but adjacent grains of chromite and olivine are interlocked. At many places the chromite layers are crossed by a system of closely spaced, parallel seams of white magnesite perpendicular to the layers and not extending into the dunite (see pl. 14B). The bands conform, in general, to the attitude of the main peridotite body. In places they are folded and cut by dikelets of saxonite (see pl. 15B). The axes of the folds are likewise consistently parallel to the linear strucutre of the peridotite body.

Linear banded ore is very common and together with the planar banding makes up most of the ore in the area. When seen parallel to the strike, linear banded ore has the same appearance as planar banded ore, but when viewed across the strike it is seen that the banding is formed by a series of parallel rods of chromite in nearly parallel layers (see fig. 3). The attitude of the linearity is consistently parallel to the elongation of the peridotite body and plunges 5° to 22° N.

The bands of chromite tend to form stacks or bundles of various dimensions surrounded by very lean dunite containing disseminated chromite. The spacing of these stacks varies but they lie within a large body beyond which the chromite is present only as a sparsely scattered accessory mineral. This body is about 2,500 feet long and 100 feet thick. It seems probable that the body will extend 200 feet or more down the dip. It strikes between N. 18°-30°W., and plunges between 5°-22°N. The ore deposits are the parts of this body in which disseminated, banded, or linear chromite is sufficiently abundant to form masses large enough to be efficiently mined and of an average grade high enough to justify mining. The Veta Chica, Cerro Colorado, Grand Falls, and Lady Gray deposits fall within this body. They are separated from each other by parts in which the concentration of chromite is less than 2 or 3 percent. The other deposits in the area, for example the Mary Lou,—lie outside of this body, and are small and scattered at random.

Deposits.—The Veta Chica claim is on the slope south of McGuffy Creek. Its long dimension trends south-southeast, roughly parallel to the slope (see pl. 27). Development consists of a few scattered pits and trenches and an adit 20 feet long, which are located in the northern part of the claim where the significantly mineralized zone occurs (see pl. 28). The deposit lies on a cliff most of which is outcrop, so that very little work has been necessary to show the ore. Chromite crops out over an area approximately 500 feet long by 80 feet wide. The deposit is bounded both on the north and south by east-west faults and the ore body itself is crossed by several faults, mostly with small displacement; however, one exposed in the adit shows an offset of about 75 feet—apparent movement, south block east.

The ore body is elongate, striking N. 10°-25° W., and dipping 45°-60° W., with its long axis plunging about 10° N. (see pl.29). Erosion has removed a large part of the central section of the ore body, and that portion just south of the fault exposed in the adit has been completely removed.

Chromite concentrations occur both as scattered short, lineate bodies and as zones of contorted layered ore (see pl. 27). In the lower third of the ore body the chromite is the lineate type, whereas the upper two-thirds of the ore body consists of several zones of layered ore, three of which are more or less continuous throughout the length of the deposit. These zones range from a few inches to a maximum of 8 feet in thickness and are separated by 5 to 25 feet of nearly barren dunite. The Cr_2O_3 content of the zones averages about 18 percent.

Because of their relative thinness, individual ore zones could only be mined on a small scale at high costs. The only possibility of developing a large tonnage would be to mine practically the whole outcrop on a large scale. The average grade of the whole deposit would obviously be far too low to mill commercially, but preliminary hand-sorting could be employed to elminate the material containing less than 5 percent Cr_2O_3. As the ore has relatively sharp contacts with the barren waste, the sorted product would approximate the grade of the zones.

It is believed that surface mapping and diamond drilling have delimited the ore body sufficiently that reserves can be estimated with reasonable accuracy. For convenience in calculating reserves, the deposit has been divided into three blocks representative of topographic and geologic features.

That part of the ore body between diamond-drill hole 11 and the southernmost fault is economically the most important. Using a tonnage factor of 10, and assuming that the whole outcrop could be mined to an average depth of 50 feet, a length of 180 feet, and a width of 60 feet, there are 54,000 short tons of ore-bearing material present. If the sorting ratio is 5:1, as seems likely, the reserves of this block are 9,000 short tons of ore averaging 20 percent of Cr_2O_3.

Similarly, if the block between diamond-drill hole 11 and the fault exposed in the adit could be mined to an average depth of 25 feet, a length of 150 feet, and a width of 48 feet, there are 18,000 short tons of material from which 3,000 short tons of ore averaging 15 percent of Cr_2O_3 could be sorted. It might be possible to mine part of the uppermost zone in this block to an additional depth of 40 feet and thus obtain 500 tons of ore averaging 25 percent of Cr_2O_3.

If the next block could be mined to a maximum depth of 50 feet (at the south end), a length of 60 feet, and a width of 60 feet, there are 9,000 short tons of ore-bearing material available. The probable sorting ratio for this block is 7:1; therefore, there are 1,125 short tons of ore averaging 11 percent Cr_2O_3. The total reserves indicated for the Veta Chica deposit are thus 13,625 short tons of ore averaging 18 percent of Cr_2O_3.

The Cerro Colorado claim lies parallel to the Veta Chica; but is offset about 50 feet to the west, and half a claim length to the north (see pl. 27). The significantly chromite-mineralized zone occurs along the western edge of the northern half of the claim and consists of several parallel zones of chromite-rich dunite, separated by several feet of barren dunite. The ore body has an elongate shape similar to the Veta Chica ore body (see pl. 30). South of a small gully the ore body is exposed by a series of pits; it strikes N. 5° to 10° W., dips about 75° W., and plunges about 15° N. North of the northernmost trench the ore is apparently offset by an east-west fault which cannot be located accurately enough to be mapped. The ore is exposed again in outcrops north of the gully, but this offset continuation is of no economic importance.

The ore zones in the main part of the ore body range in thickness from 6 inches to 4 feet and average 20 percent of Cr_2O_3. They are separated by 1 to 10 feet of waste so the maximum width of the ore body is about 50 feet. The strike length of the ore body is about 400 feet. The ore shows marked layering, but it also has a definite linear structure imparted by rods of chromite and the axes of folds in the layers. The linear structure parallels the strike and plunge of the ore body. Ore exposed at the northernmost end and also at the south end of the ore body exhibits evidences of brecciation and stronger contortion. These features are interpreted as resulting from shearing and compressive forces affecting the relatively unprotected ends and edges of the ore body prior to complete consolidation. The ore is not as contorted, however, as is ore in the Veta Chica deposit.

It is assumed that the entire width of the ore body could be mined and sorted as suggested for the Veta Chica deposit. The ore body has an average depth of 40 feet, length of 450 feet, an average width of 20 feet, and is estimated to contain 36,000 short tons of ore-bearing material. It is estimated that the sorting ratio is about 3:1; therefore, the reserves of the deposit are 9,000 short tons of ore averaging 20 percent of Cr_2O_3. A small part of the ore might be sorted to meet the specifications for "low-grade A" ore (see footnote p. 62).

The Veta Grande claim is on the nose of the ridge south of McGuffy Creek. The southern end of the claim is within a few hundred feet of the peridotite-quartz diorite contact. Most of the ore shipped from the area during the last war came from this claim, then called the Red Butte (see p. 56) and operated by G. A. Reichman and George Milne. Additional mining has been done on the property during the past few years, and discrepancies between the findings of Rynearson and Smith 31/ and the authors' results are to be ascribed to this fact and to the greater detail in which this work was done. The ore is in a narrow dunite body that lies within the lherzolite about 100 feet southwest of the main dunite zone (see p. 56). It consists of a zone of mostly linear ore about 20 feet wide and 125 feet long. Striking N. 30°-35° W., and plunging 15°-25° NW. This zone is developed by one large cut across the zone and several small ones. Three hundred feet to the northwest is a showing of chromite in a pit which lies on the projection of the main zone (see pl. 31), but the mineralization is not continuous between. There is also a small amount of contorted layered chromite, notably a 4-foot zone dipping southwest and exposed in a short adit 10 feet long. Some orbicular ore was found in the dump, and a few pounds were observed in place. There has been secondary alteration of the dunite along cross fractures, resulting in the formation of talc, serpentine, and exceptionally well-developed crystals of kämmererite.

According to reports some very high grade ore was mined from the large cut but very little is left in sight. From the showings in the cuts, indicated reserves would amount to not more than 1,000 tons of ore averaging 15 percent of Cr_2O_3.

The Mary Lou claim, called the Octopus during World War I, is located in the northwest corner of sec. 31, T. 45 N., R. 10 W., (see pl. 27).

31/ Rynearson, G. A., and Smith, C. T., op. cit., p. 304, 1940.

The ore has been opened up by several pits and a short adit now completely covered (see pl. 32). It occurs just north of the gneissic diorite-peridotite contact which here trends east by north. The ore is in general quite highly sheared and fractured and its original structure largely obliterated; however, layering and a linear element with a strike N. 50°-60° W. and plunging 10° NW. can be recognized. On the western margin of the ore is a small quantity of orbicular chromite with the orbicules flattened so their longest axes are parallel to the linear structure (see pl. 9). This is the only locality in the area in which orbicular ore occurs. Eighty tons of ore were mined from the claim during the last war but not shipped. This ore averages less than 40 percent of Cr_2O_3. The remaining reserves of this grade would probably not amount to more than a few hundred tons.

The Lady Gray claim has been located by Hollis Anderson of Scott Bar on three unprospected ore zones southeast of the Veta Chica claim. The ore represents a continuation of the same general zone in which the Veta Chica ore occurs. The central and lower zones are exposed for about 50 feet along the strike and average about 1 foot in thickness. The central zone has an exposed depth of 25 feet and appears to pinch out at the top and bottom. The upper zone is very low grade and appears to be insignificant. It is probable that not more than 200 tons of ore containing 20 to 25 percent of Cr_2O_3 could be produced from the deposit.

The Grand Falls, Grand Canyon, and Bluestone claims are owned by Mrs. D. R. Moroney of Hamburg. The first two are located on a zone of linear and planar ore (see pl. 27) which is exposed in a few small pits. The zone, if continuous between the pits, has a strike length of 900 feet and averages 2 or 3 feet in width. There is indication that the ore is fairly continuous, for float can be found at several places between the pits; however, the ore probably is very irregular and reserves are not more than 1,000 tons of ore containing 15 to 20 percent of Cr_2O_3. The Bluestone claim and other scattered localities show small amounts of chromite which have no economic importance.

Two chromite claims, Black Spot No. 1 and No. 2, have been located on the ridge north of McGuffy Creek (see pl. 6) by Elmer Weeks of Scott Bar. In both claims the chromite occurs as nodules. The chromite of Black Spot No. 1 was found in a slide and that of Black Spot No. 2 in a small outcrop on the top of the ridge.

Three open cuts in disseminated and banded chromite on the eastern edge of sec. 19, T. 45 N., R. 10 W., were visited (see pl. 6). Some of the chromite bands are 2 inches wide, but the total amount of chromite cannot be more than a few tons.

Reserves.—It is indicated that approximately 25,200 short tons of ore that will average about 18 percent of Cr_2O_3 can be mined by large-scale selective methods from the claims in the area. If carefully sorted, it is possible that a small proportion of the total reserves would meet requirements for "low-grade A" ore.32/ Reserves for each claim are as follows:

	Short tons
Veta Chica	13,625
Cerro Colorado	9,000
Veta Grande	1,000
Grand Falls and Grand Canyon	1,000
Mary Lou	375
Lady Gray	200

32/ According to the specifications of the Metals Reserve Co.; see Averill, C. V., Chromium: California Jour. Mines and Geol., vol. 38 p. 79, 1942.