UNITED STATES DEPARTMENT OF THE INTERIOR
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GEOLOGICAL SURVEY
W. E. Wrather, *Director*

Bulletin 945

STRATEGIC MINERALS INVESTIGATIONS
1944

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UNITED STATES DEPARTMENT OF THE INTERIOR
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GEOLOGICAL SURVEY
W. E. Wrather, Director

Bulletin 945-A

GEOLOGY OF THE GREY EAGLE AND SOME NEARBY CHROMITE DEPOSITS IN GLENN COUNTY, CALIFORNIA

BY

G. A. RYNEARSON AND F. G. WELLS

Strategic Minerals Investigations, 1944

(Pages 1-22)

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CONTENTS

ILLUSTRATIONS

GEOLOGY OF THE GREY EAGLE AND SOME NEARBY CHROMITE DEPOSITS IN GLENN COUNTY, CALIFORNIA

By G. A. Rynearson and F. G. Wells

ABSTRACT

The principal deposits of chromite in Glenn County, Calif., occur in an elongate sill-like mass of peridotite, one of a group that forms a more or less continuous belt, trending a few degrees east of north, along the eastern edge of the northern Coast Range. The peridotite has been intruded into phyllites and schists, probably of the Franciscan formation (Jurassic?), into argillites and altered volcanics that are post-Franciscan and may form the basal part of the Knoxville, and into shales, sandstones, and conglomerates of the Knoxville formation (Jurassic and Lower Cretaceous).

The peridotite mass is complex; it consists of saxonite, dunite, wehrlite, and pyroxenite, listed in order of abundance. The ore is all in dunite. It consists of chromite that may be evenly disseminated or may be concentrated in layers. A little of the ore contains 70 to 80 percent chromite, but the bulk of it contains about 26 percent or less, and must be concentrated to yield a marketable product.

The Grey Eagle mine contains the largest deposit in the area, its reserves amounting to possibly 174,000 short tons with an average grade of 13 percent Cr_2O_3. The Black Diamond mine has total reserves of 23,000 short tons containing 5 to 10 percent Cr_2O_3 and the Black Diamond No. 9 has total reserves of 22,250 short tons, averaging 8 percent Cr_2O_3. Twenty-one other deposits occur within the area, but only eight of them are potential producers, and no one of these eight contains a total reserve greater than 1,500 short tons.

The Rustless Mining Corporation has constructed and is operating a concentrating plant of 200 tons daily capacity, which produces 50 short tons a day of concentrates that contain, on the average, more than 45 percent Cr_2O_3 with a chromium-iron ratio of 2.65.

INTRODUCTION

The chromite deposits described in this report lie within an area of 3 square miles in sec. 19, T. 22 N., R. 6 W., and secs. 13, 14, 24, and 25, T. 22 N., R. 7 W., Glenn County, Calif. (see pl. 1). The area is on the eastern edge of the northern Coast Ranges of California, and its rugged topography ranges in altitude from 1,200 feet at Rustless to 3,630 feet on Red Mountain. The climate is hot and dry during the summer and mild, but wet, during the winter. The mining camp, called Rustless, is 2 miles west of a county road to Willows, the commercial center of the region, which is 36 miles to the southeast, on U. S. Highway 99W and on the main line of the Southern Pacific Railway. Ore is trucked 20 miles on the county road to a railroad spur at Fruto.

Geologic study of the area was begun in July 1940 by G. A. Rynearson, C. R. Warren, and R. C. Pruess, under the supervision of F. G. Wells. H. E. Hawkes, Jr., R. T. Littleton, and D. P. Wheeler, Jr., joined the party during the field season, which was concluded early in October. In June 1941, G. A. Rynearson and R. T. Littleton resumed the investigations, cooperating with Mr. G. D. Jermain of the U. S. Bureau of Mines in an exploration program, and F. W. Cater, Jr., of the Survey aided also in this phase of the work. Field work was continued intermittently until March 1942. Most of the area was mapped by plane-table methods, but part of it was mapped by making aneroid traverses tied to triangulation control on aerial photographs. The report was prepared mainly by G. A. Rynearson with the assistance of F. G. Wells, and friendly and helpful criticism has been given by F. C. Calkins.

The Grey Eagle, Grey Eagle Extension, and Black Diamond claims were trenched, sampled, and diamond-drilled by the U. S. Bureau of Mines during the period from May to August 1941. This work was under the direction of E. D. Gardner and was carried out by G. D. Jermain as engineer in charge. The writers are grateful for their cooperation and for being able to use the results of Mr. Jermain's work. Thanks are also due to the personnel of the Rustless Mining Corporation for their constant cooperation and courtesy, and to the U. S. Forest Service and to many local residents for various kindnesses.

The publication of this report has been delayed due to the many demands made on the personnel of the Geological Survey during the war. Since the first draft of this report was submitted in March 1942, the Rustless Mining Corporation has mined out the Grey Eagle deposit and has done work on the Black Diamond claims. As mining has, to a large degree, verified the inferences and conclusions made in the original report it has seemed adequate to correct the report where necessary rather than further to delay publication by completely rewriting it. The chromite deposits on Red Mountain are excellent examples of the disseminated type of chromite occurrences found in California and Oregon and a complete geologic description of them is of general interest at this time.

HISTORY AND PRODUCTION

The Climax Chrome Mining Co. first located claims on chromite deposits in Glenn County in 1890 and mined chromite ore until 1893. The deposits then lay idle until 1915, when G. Luce and A. Luce resumed mining operations. From 1916 until the collapse of the market in 1918 the deposits were worked by the California Chrome Co. and several private operators. After World War I, the principal properties were acquired successively by the International Chrome Mines, Inc., the Darlington Rustless Steel & Iron Co., Ltd., and the U. S. Chrome Mines, Inc., which leased its holdings to the Rustless Mining Corporation in 1937. After the exploration by the U. S. Bureau of Mines in 1941, the Rustless Mining Corporation constructed a

200-ton concentrating plant, and it began producing concentrates in February 1942. The production of the district is shown in the following table:

Production of chromite in Glenn County 1/

Year	Type of ore	Ore shipped (long tons)	Grade (percent Cr_2O_3)
1893............	Crude ore...	3,319	....
1894-1914.......	....	None	None
1915............	Crude ore...	893	....
1916............	do........	3,000	....
1917............	do........	879	47
1918............	do........	1,772	50
1919-1941.......	....	None	None
1942............	Concentrates	10,020	46
1943............	do........	17,738	45.6

1/ The production data prior to 1918 have been taken from the publications of the California Division of Mines; these do not agree in all instances. Production for 1918 has been taken from the unpublished data of the U. S. Bureau of Mines and for 1942 and 1943 from the records of the Rustless Mining Corporation.

Guy E. Dent and Hugo E. Kuehn of the Rustless Mining Corporation, with the assistance of F. W. Lee of the Geological Survey, surveyed the Grey Eagle deposit by magnetic and electrical resistivity methods in November and December 1937.

The deposits have been described briefly by Logan 1/ and by Allen.2/

GEOLOGY

The Glenn County chromite deposits occur in a sill-like body of peridotite, a rock commonly called serpentine by the miners. This mass forms parts of a more or less continuous belt, trending a few degrees east of north, along the eastern edge of the northern Coast Ranges. It is bounded on the west and south by phyllites and schists tentatively correlated with the Franciscan formation, and by argillites and altered volcanic rocks whose age is uncertain but is possibly late Jurassic. On the east the peridotite is faulted against shales, sandstones, and conglomerates of the Knoxville formation. Many small diorite dikes cut the peridotite (see pl. 2).

Older rocks

Phyllites and schists.—The oldest rocks in the area are regionally metamorphosed sedimentary and volcanic rocks. Those of sedimentary origin are layered rocks characterized by various degrees of foliation. The layers range from a fraction of an inch to several feet in thickness, and successive layers may differ either in color or grain size or both. Where the rocks are fresh their colors range from light gray to dark gray or black; where weathered they are greenish gray, buff, and

1/ Bradley, W. W., and others, Manganese and chromium in California: Cal. Min. Bur. Bull. 76, pp. 146-148, 1918.

2/ Allen, J. E., Geological investigation of the chromite deposits of California: California Jour. Mines and Geology, vol. 37, pp. 133-134, 1941.

reddish brown. The grains in most of the layers are too fine to be distinguished under a hand lens, but in many layers they range up to 2 millimeters in diameter and in a few they attain diameters of several inches. The layers also differ in composition; some consist mainly of quartz, others are mainly composed of feldspars and dark-colored minerals. The foliation is parallel, or mainly so, to the layering. Some of the schist cleaves into paper-thin plates. Although in most places there is merely a sheen on cleavage faces, due to a thin coat of fine-grained micaceous minerals, the formation comprises some highly crystalline, crumpled schist. Glaucophane has been found at one place near the contact of schist with peridotite. Veins and lenticular masses of quartz are abundant in these rocks, a feature which helps to distinguish them from some similar but younger rocks that occur in the district.

The volcanic rocks occur in beds that are tens of feet thick. They are gray or greenish gray and weather brown. Although they are fine-grained their igneous texture can usually be detected, and they are less distinctly foliated than the rocks of sedimentary origin.

These sedimentary and igneous rocks closely resemble parts of the Franciscan formation that have been metamorphosed, and they are therefore correlated with the Franciscan, which is commonly believed to be of Jurassic age.

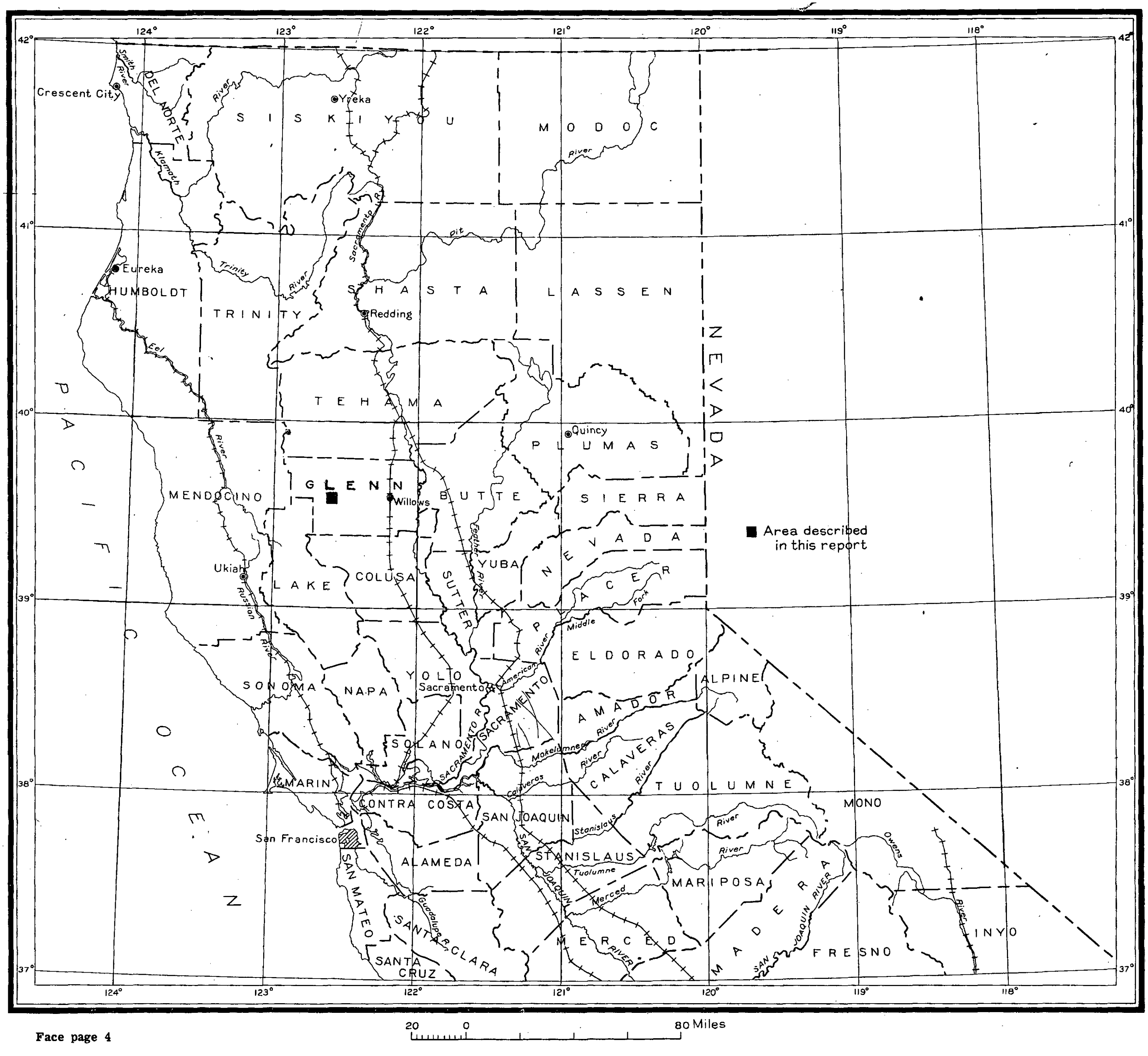
Knoxville formation

Argillite and associated volcanic rocks.—Several small areas of slightly metamorphosed volcanic and sedimentary rocks occur along the southern contact of the ultramafic rocks with the Franciscan formation. Dark gray and black argillite is the predominant sedimentary rock in this unit, but some reddish ferruginous chert also is present. The argillite is composed of fine grains of quartz and feldspar in an argillaceous matrix. Recrystallization is not evident, but fracture cleavage is well developed and pencil structure is common. Quartz veinlets fill a few of the fractures. The volcanic rocks are greenish gray, weathering to brown. They are andesitic to basaltic in composition and commonly show textures characteristic of andesite and basalt. Their feldspar is plagioclase, considerably altered to saussurite; they contain augite, which is partly altered to amphibole and to chlorite and related minerals. They may have contained hypersthene, but none remains. In some places an intimate mingling of volcanic material with argillite and the presence of numerous veinlets and lentils of calcite suggest that the volcanic material flowed into a basin in which limy muds were accumulating.

Although the relations of these rocks are obscure in this area, a study of similar rocks to the north indicates a closer affinity to the Knoxville than to the Franciscan formation. The rocks in question are, therefore, assumed to represent the lowermost part of the Knoxville formation and to be of Upper Jurassic age.

Main body.—The sedimentary rocks east of the peridotite body are correlated with the Knoxville formation, of Upper Jurassic and Lower Cretaceous age, because they contain invertebrate fossils 3/ which, though poorly preserved, indicate

3/ These fossils were identified by Ralph W. Imlay.



SISKIYOU
MODOC
DEL NORTE
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TRINITY
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PLUMAS
GLENN
BUTTE
SIERRA
NEVADA
MENDOCINO
LAKE
COLUSA
SUTTER
YUBA
PLACER
ELDORADO
SONOMA
NAPA
YOLO
SACRAMENTO
SOLANO
ALPINE
AMADOR
CALAVERAS
TUOLUMNE
MONO
MARIN
CONTRA COSTA
SAN JOAQUIN
STANISLAUS
ALAMEDA
SAN MATEO
SANTA CLARA
SANTA CRUZ
MARIPOSA
MERCED
MADERA
FRESNO
INYO
PACIFIC OCEAN
Crescent City
Yreka
Eureka
Redding
Quincy
Willows
Ukiah
Sacramento
San Francisco
Area described in this report
20 0 80 Miles

such an age. The strata strike a few degrees west of north and dip 45° to 80° E. except along the contact with the peridotite, where they are slightly contorted and overturned. Thin-bedded shales and siltstones predominate, but beds of fine- to coarse-grained sandstones and of conglomerate are also present. The finer-grained rocks are light to dark gray; the coarser sandstones are gray and weather to a rusty brown.

The sediments are composed of grains and pebbles of quartz, feldspar, altered ferromagnesian minerals, chert, and volcanic rocks. The finer-grained beds are cut by numerous veinlets of calcite and gypsum. Some sandstone beds contain abundant marine invertebrate fossils and carbonaceous fragments, and fragments of lignite have been found in the conglomerate. Occasional outcrops of hornfels along the contact with peridotite suggest that the sediment was baked by the intrusive, although this contact is on a fault.

The shales are easily eroded, but two beds of conglomerate and some beds of coarse-grained sandstone along the eastern edge of section 19 are more resistant and form a prominent ridge. As the sandstone contains thick-shelled marine fossils, carbonaceous fragments, and occasional ripple marks, it probably was deposited in shallow water off shore.

Peridotite and associated dikes

In the area mapped the peridotite mass is 2 miles wide (see pl. 2). This width persists for at least 3 miles to the north, but at the southern edge of the area the mass narrows abruptly, and a mile to the south it is only a quarter of a mile wide. The mass is rudely tabular and appears to be parallel, or nearly so, to the bedding of the rocks into which it has been intruded. The intrusive mass is not homogeneous but comprises four distinct varieties of peridotite, which, in order of abundance, are saxonite, dunite, wehrlite, and pyroxenite. All these seem to be contemporaneous except some of the saxonite, which, for the reasons given below, is believed to have been intruded at a separate stage. Parts of the peridotite mass are largely altered to the mineral serpentine, but these parts have not been distinguished on the map.

The peridotite is cut by dikes of pyroxenite, diorite, and perhaps other rocks.

Saxonite.—The predominant variety of peridotite in the area is saxonite, a rock composed of olivine and enstatite, with or without accessory chromite. It shows all degrees of alteration to serpentine. The least altered saxonite, exposed on Heifer Camp Creek, is dark green; the crystals of enstatite are distinguishable by their platy cleavage but are not conspicuous. More thoroughly altered saxonite is predominantly dark greenish gray, and much of it is spotted with lighter-gray pseudomorphs of bastite, which represent completely altered enstatite crystals. Weathered surfaces of saxonite are buff or brown, and are commonly studded with green or gray crystals of enstatite or bastite, which stand out in relief.

The rocks classed as saxonite in this report contain from 5 to 80 percent of enstatite. The enstatite crystals average about 5 millimeters in length, but crystals over 1 centimeter in length are common in the enstatite-rich phases. Although the olivine, which is largely serpentinized, appears fine-grained in hand specimens, it is seen in thin sections to form crystals that average about 5 millimeters in diameter and attain a maximum diameter of 2 to 3 centimeters. Locally, especially near dunite masses, the saxonite has a distinct linear or layered structure because of the rough layering or alinement of pyroxene crystals in an otherwise homogeneous rock.

There is evidence that the saxonite in the southeastern part of the area (see pl. 2) represents a separate stage of intrusion. This rock is essentially uniform, enclosing very few dunite bodies and, so far as known, only one body of chromite ore. It is all thoroughly altered to serpentine. Its uniformity is in striking contrast with the usual heterogeneous mixture of varietal types, the numerous chromite deposits, and the unequal serpentinization which characterize the remainder of the peridotite.

Dunite.—The rocks called dunite in this report consist predominantly of olivine, with accessory chromite and more or less serpentine derived from olivine, being virtually free from pyroxene or its alteration products. Large and small masses of such rock are scattered through the peridotite. In many places it is difficult to make a rigid distinction between dunite and saxonite because the two grade into each other. Most of the dunite masses are lens-shaped; some are tabular and others are blocky or irregular in shape. The largest dunite mass, exposed on Manzanita Ridge in the northwestern part of the area (see pl. 2), is more than 500 feet wide, and although it has not been completely delimited it is believed to be tabular in shape. Most of the dunite masses are only a few tens of feet wide and less than 100 feet long, and a great many that are only a few yards wide and a few tens of feet long are scattered through the saxonite.

Freshly broken dunite where least altered is dense in texture and dark green or almost black in color, but weathered outcrops are light brown or buff, and their surfaces are rather smooth but appear granular like a medium-grained sandstone. The olivine is more or less altered to serpentine. Under the hand lens the change from fresh dunite to highly serpentinized dunite is marked by a change of texture from dense granular to waxy and by a deepening of color.

All of the dunite contains half a percent or more of chromite as an original accessory mineral. In a few places the chromite is so concentrated as to form 20 percent or more of the rock, and such chromite-rich bodies, where of sufficient size, constitute ore.

Wehrlite.—Several small masses of a distinctive rock known as wehrlite occur in the peridotite body. The wehrlite originally contained 10 to nearly 100 percent of the monoclinic pyroxene augite, the rest being mainly olivine, rarely accompanied by accessory chromite. The olivine has been completely altered to dark greenish-brown serpentine. Fresh augite is dark green, but if weathered it is light green, so that in weathered wehrlite the contrast between the pale augite and the dark serpentine produces a characteristic mottled appearance.

The wehrlite masses are poorly exposed, and their relations to enclosing rocks are thus obscure. They appear to be associated only with the dunite, into which they grade by a decrease in the proportion of augite. In places wehrlite is interlayered with dunite, and near contacts crystal-thick layers of augite are enclosed in the dunite.

Dike rocks.—The saxonite, dunite, and chromite are cut by thin dikes of pyroxenite consisting of coarsely crystalline enstatite. Most of these are only 1 or 2 inches thick, and the largest is only about 15 inches thick, but many of them can be followed for several hundred feet. Some are offset by faults.

The ultramafic rocks are also cut by many gray to greenish-gray dikes and other intrusive bodies of dioritic composition. These dikes are medium- to fine-grained, and most of them are even-grained, with ophitic texture, though some are slightly porphyritic. Their two chief constituents, nearly equal in abundance, are altered andesine and the monoclinic pyroxene, pigeonite, much of which is replaced by amphibole. Nearly all of the dioritic dikes were injected along previously formed joints and shear zones, and there is evidence of post-diorite movement also along many of these fractures. The largest dike seen, which is more than 1,500 feet long and about 500 feet wide, lies along Heifer Camp Creek in section 23, outside of the mapped area. Besides typical dikes the diorite forms fairly large irregular and small bloblike masses. A large proportion of the diorite bodies are too small to be mapped.

The peridotite adjacent to some dikes is altered to pure white talc or, more commonly, to coarsely crystalline chlorite. At a few places the chlorite is stained with chrysocolla and contains disseminated grains of native copper, partly oxidized to cuprite.

Some of the diorite dikes are bordered by small reeflike masses of light-colored, fine-grained rocks of uncertain composition. Zoisite, chlorite, a fine-grained pyroxene, and a mineral which may be grossularite were distinguished in some thin sections of these rocks, but the other minerals present could not be identified. Most of the reefs are in shear zones adjacent to the diorite dikes, though diorite is not associated with all of them. In a few places the diorite grades into the reef-rock by the gradual loss of recognizable feldspar and pyroxene. It is believed that the rocks are of hydrothermal origin, having presumably been formed by the action of solutions from or accompanying the diorite intrusion upon peridotite and serpentine. Their association, appearance, and composition are similar to the rodingite found in New Zealand.4/

Structure

Foliation, contacts, and joints.—The foliation of the Franciscan rocks is roughly parallel to their contacts with ultramafic rocks, but the dip of the foliation is usually less steep than that of the contact. The contact on the west side of the area is regular and is vertical or dips steeply to the east. It bends sharply to the east in the SE¼ of section 26 and again makes a sharp bend to the south in the southwest corner of section 30. The Franciscan rocks are most contorted in the southern part of the area, and their contacts with the ultramafic rocks and the supposedly lower Knoxville rocks are irregular.

The contact of the large saxonite body in the southeastern part of the area with the rest of the peridotite is well defined. It trends westward across the central part of section 30 into section 25, where it bends to the southwest.

4/ Grange, L. I., On the "rodingite" of Nelson: New Zealand Inst. Trans., vol. 58, pp. 160-166, 1927.

Masses of dunite and wehrlite enclosed in the peridotite show a rudely parallel orientation of their long and intermediate axes. The attitude of these masses varies from place to place, but they generally strike east and west and dip 15° to 40° N.

A sheeted structure is conspicuous in much of the peridotite and is especially well developed in some of the dunite. In the saxonite and wehrlite there is planar arrangement of the pyroxene crystals, usually best developed at the boundaries with dunite. In the dunite the sheeting is represented by closely spaced parallel fractures, which, especially near the borders, may impart a shaly character to the rocks. In general the sheeting is nearly parallel to the elongation of the dunite masses, but it commonly crosses their shorter dimensions at a low angle.

It is believed that this structure resulted from differential flowage or fracture, or both, in the partly consolidated magma. The evidence of flowage is most conspicuous in the saxonite and wehrlite, because of the alinement of the pyroxene crystals. While these rocks were still fluid the dunite had consolidated sufficiently to fracture.

Systematic jointing is not developed in all parts of the peridotite. The most prominent joint system is in the rocks along Heifer Camp Creek in the eastern part of section 24. The joint planes here have an average strike of about N. 20° W. and dip nearly vertically. They are 1 foot to 10 or 15 feet apart, and movements on them of a few inches to several feet are indicated by displacements of thin pyroxenite dikes. Elsewhere the joints are erratic in strike, but all of them dip steeply.

Faults.—The most prominent fault in the area is a reverse fault which separates the peridotite from the Knoxville formation. This fault is curved, but in general it strikes nearly north and dips 45° to 65° W. The peridotite adjacent to the fault is sheared and brecciated in a zone 100 to 500 feet wide. A cross-fault offsets the main fault near the mill, but it could not be traced through this shear zone.

Although the peridotite is commonly sheared along its contacts with Franciscan rocks, its contacts are believed to be essentially intrusive in character.

Many faults and shear zones cut the peridotite. Most of the faults can be traced only for short distances, because in the highly incompetent serpentinized peridotite the shearing stresses tend to be dissipated in many minute breaks. Offset outcrops of diorite locally aid in tracing faults, but this evidence cannot be relied upon. The amount of displacement along these faults is difficult to determine. The width of gouge or of sheared serpentine does not give any reliable measure of the throw of any given fault. Displacements of dunite masses and ore bodies, however, indicate throws of some tens of feet, or at most a few hundred feet.

ORE BODIES

Mineralogy

The only ore mineral found in the deposits is chromite, a black, submetallic mineral—brown in finely powdered form—

whose specific gravity ranges from 4.1 to 4.9. Chromite 5/ is an isomorphous mixture of the six compounds: ferro-chromite ($FeO.Cr_2O_3$), magnesio-chromite ($MgO.Cr_2O_3$), spinel ($MgO.Al_2O_3$), hercynite ($FeO.Al_2O_3$), magnetite ($FeO.Fe_2O_3$), and magnesio-ferrite ($MgO.Fe_2O_3$). These compounds may be combined in any ratio to form chromites of different composition. The chromite from Glenn County contains 49 to 57 percent Cr_2O_3 and 14 to 20 percent FeO, the composition differing in different ore bodies. Analyses of two samples of the chromite, which had been purified as completely as possible, are given below:

Analyses of chromite from Glenn County, California
[R. E. Stevens, analyst]

	DPW-1-40	DPW-3-40
Cr_2O_3	56.98	56.75
Al_2O_3	11.03	9.93
Fe_2O_3	4.81	6.03
FeO	11.40	12.94
MgO	14.55	13.00
MnO	.16	.16
CaO	.14	.24
TiO_2	.18	.22
SiO	.40	.40
H_2O+	.20	.15
Total	99.85	99.82
Ratio Cr/Fe	3.19	2.72
Specific gravity	4.368	4.34
Impurity	Serpentine	Serpentine

DPW-1-40. Grab sample from block 10 of the Grey Eagle mine, representing a 30-foot width of disseminated ore averaging 37.4 percent Cr_2O_3.

DPW-3-40. Channel sample from upper open cut of the Black Diamond No. 10 claim, representing a 12-foot width of disseminated ore averaging 16.4 percent Cr_2O_3.

The purple chromium chlorite kaemmererite and the green chromium garnet uvarovite are occasionally found to be associated with concentrations of coarse-grained chromite. Olivine ($(Mg,Fe)_2SiO_4$) is the only primary gangue mineral, and its alteration product serpentine ($H_4Mg_3Si_2O_9$) usually predominates in the gangue. Magnesite ($MgCO_3$), talc ($H_3Mg_3(SiO_3)_4$), and chalcedony or opal occur in small quantity as veinlets and fracture fillings.

Character of ore

Most of the ore in the district consists of chromite grains disseminated in dunite. The chromite may be disseminated evenly, or it may be concentrated in streaks or layers that are separated either by lean disseminated ore or by barren dunite. The layers commonly have sharp boundaries. Where the chromite grains are evenly disseminated they are of relatively uniform size in any one part of the ore body, but they may range from 0.5 millimeter to 2.5 millimeters in diameter throughout the ore body as a whole. Where concentrated in rich streaks the grains, with few exceptions, are especially coarse. The tenor of the ores ranges from a few percent to 60 percent of chromite.

5/ Stevens, R. E., Composition of some chromites of the western hemisphere: Am. Mineralogist, vol. 29, pp. 1-34, 1944.

In some deposits the ore consists of sharply bounded stringers and irregular or lens-shaped masses of nearly pure chromite, enclosed either in barren dunite or in disseminated ore. Such ore is characteristically coarse-grained, with crystals ranging up to 1 centimeter in diameter.

Subordinate quantities of rich ore occurring separately or with the other types consist of sharply bounded spheroidal or ellipsoidal masses of chromite. These range from 0.5 millimeter to 2.5 centimeters in diameter, but in any one deposit they are of nearly equal size. The chromite grains in the nodules are anhedral. They are separated by thin films of introduced serpentine and by small irregular masses of serpentine presumably derived from olivine, in contact with which the chromite grains present rounded and embayed surfaces, as if they had been partly replaced by serpentine. Clusters of chromite crystals resembling imperfectly developed nodules were noted in one of the deposits.

Partial analyses of chromite from the Grey Eagle mine have indicated that the chromite in coarse-grained concentrations is richer in Cr_2O_3 and poorer in FeO than that in adjacent finer-grained disseminated ore. Chromite from the dark lens shown in figure 1 contains 53.31 to 56.10 percent Cr_2O_3 and 14.28 to 15.73 percent FeO, whereas chromite from the adjacent disseminated ore contains 49.54 to 52.26 percent Cr_2O_3 and 15.59 to 17.92 percent FeO. If the coarse-grained concentrated chromite in the lens crystallized before the disseminated chromite, the greater iron content of the latter supports the hypothesis that the iron content of the melt increases during the early stages of crystallization.

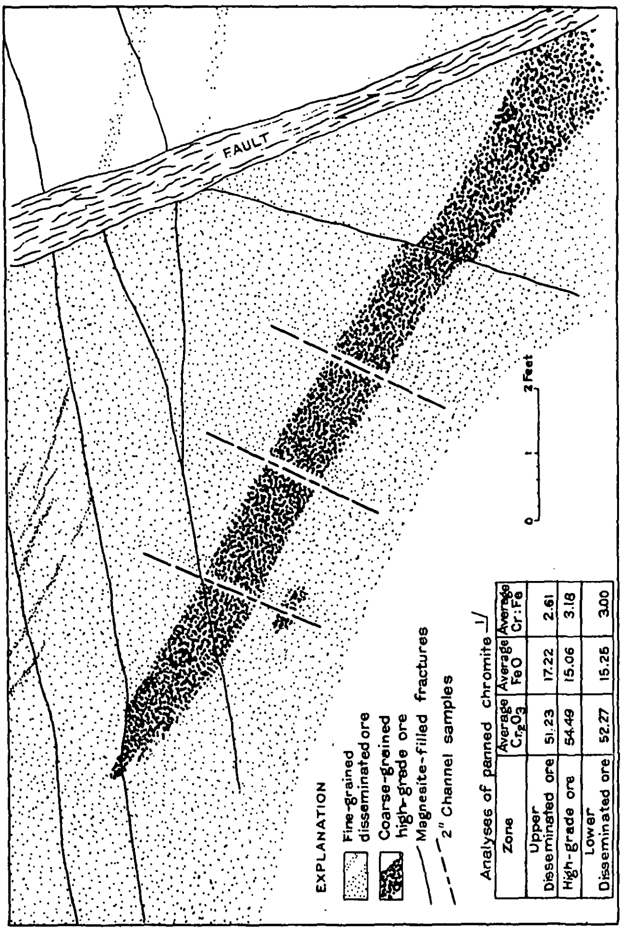
Localization

Field studies have indicated that concentrations of chromite were formed only in dunite. Some ore bodies have been brought into contact with saxonite by faulting, but all the unfaulted ore bodies in the area are wholly enclosed by dunite with the exception of a single tabular mass of solid chromite 1 foot thick, which has dunite on its footwall and saxonite on its hanging wall. Since all the other ore bodies are in dunite, it is probable that dunite originally formed both walls of this one but was broken away from the ore before the enclosing saxonite was completely consolidated.

Most of the bodies are well within the borders of the enclosing dunite, and their longer axes, as well as individual layers of chromite, lie roughly parallel to the nearest contact between dunite and saxonite. However, these relations have been disturbed locally by flowage and contortion prior to consolidation and by minor faulting. A single mass of dunite may contain several ore bodies, but some do not contain any.

Origin

Chromite is generally believed to crystallize from a silicate melt, but its genetic relation to associated olivine and pyroxene is often a subject of controversy. Certain textural features of the chromite deposits in Glenn County are believed to indicate that the chromite crystallized before the pyroxene and also before the major part of the olivine. Chromite of hydrothermal origin, if present at all, occurs only in insignificant amount. The chromite is essentially an original constituent of the enclosing rock. It would hardly occur to one to regard it otherwise where it is sparsely disseminated, as magnetite is in diorite; it is only its local concentration that might be regarded as a result of secondary processes; even this concentration, however, is believed to have occurred before the dunite was wholly solidified.



Analyses of panned chromite 1/

Zone	Average Cr_2O_3	Average FeO	Average Cr:Fe
Upper Disseminated ore	51.23	17.22	2.61
High-grade ore	54.49	15.06	3.18
Lower Disseminated ore	52.27	15.26	3.00

Figure 1.—Section showing lens of high-grade ore in disseminated ore at Grey Eagle mine.
1/ Assays by Rustless Mining Corporation.

That chromite crystallized early is indicated by several lines of evidence. Minute spheroidal or ellipsoidal blebs of olivine in chromite appear to represent globules of liquid olivine which were trapped in crystallizing chromite, and adjacent blebs of olivine appear to have coalesced, to crystallize as a unit with the same optical orientation, further indicating that this olivine was liquid when the chromite crystallized. On the other hand, small chromite crystals, many of them well formed, are enclosed by large olivine crystals in both dunite and saxonite, and such crystals, unlike the rounded blebs just described, would appear to have been formed earlier than the enclosing mineral. Borders of chromite grains, moreover, commonly have rounded re-entrants suggesting that they were corroded by liquid olivine. That liquid olivine existed after complete crystallization of chromite is shown by veinlets of chromite-free dunite which crosscut layers of chromite in the ore. It therefore seems clear that chromite began to crystallize before olivine, and that olivine continued to form after chromite had ceased to crystallize; it is probable, however, that the crystallization periods of the two minerals overlapped.

The marginal fracture-sheeting in the dunite masses is not present in the surrounding peridotite. This indicates that the dunite consolidated earlier. If, then, the chromite had been of hydrothermal origin it might have been expected to form in large part near the contacts, whereas most concentrations of chromite occur well within the borders of dunite masses, giving still further evidence that the chromite accumulated before the consolidation of the dunite.

The chromite crystallizing from the magma, together with a part of the olivine which had already begun to crystallize, appears to have been accumulated to form bodies of chromite-rich dunite. Continued crystallization of olivine and of the small amount of chromite still in solution formed the dunite that envelops the ore bodies. Upon further cooling of this crystal "mush," additional olivine and perhaps some chromite crystallized from the interstitial liquid, the process continuing until the mass became sufficiently rigid to allow the expulsion of the remaining liquid by differential stresses acting on the mass. The accumulation of the chromite-rich dunite probably took place before intrusion, and the clots of crystal mush moved as free units in the more liquid magma.

Size and grade of ore bodies

Nearly all of the ore bodies in the district consist of low-grade milling ore. Although the tenor of this ore varies greatly within short distances, it is generally above the minimum of 5 percent Cr_2O_3 required by present milling practice. Some of the deposits contained, and may still contain, small quantities of ore that is rich enough to be shipped crude. Production prior to 1942 was limited to this type of ore and some of it may be produced in the future.

As panned concentrates from several of the deposits have assayed 49 to 57 percent Cr_2O_3, it is believed that the chromite in all of the deposits contains on the average at least 50 percent of Cr_2O_3. With a little practice, satisfactory estimates of Cr_2O_3 percentage can be made by estimating visually the percentage of chromite in the ore and dividing the result by 2.

Ore bodies nowhere constitute more than a small fraction of the dunite mass that encloses them. The largest known ore body is 750 feet long, 10 to 50 feet thick, and 250 feet in maximum width. In general, however, the ore bodies are only 2 to 10 feet thick, 20 to 50 feet wide, and 25 to 100 feet long. Many of the smaller deposits contain too little ore to justify a mining operation unless the demand for chromite is greatly stimulated.

Reserves

In calculating the reserves of the deposits, an attempt has been made to subdivide these reserves into three classes, defined somewhat arbitrarily, according to the accuracy and completeness of the data upon which they are based. Ore that is blocked out in workings or recoverable from dumps is called measured ore. Ore whose volume has been computed from dimensions that are partly known and partly indicated by geologic evidence is called indicated ore. Ore whose volume is computed wholly on the basis of geologic inference is called inferred ore. Reserves of each class for each notable deposit in the district are tabulated on the following page.

A 200-ton mill designed to produce 50 tons of concentrates a day was put into operation by the Rustless Mining Corporation on March 1, 1942, and has been in continuous operation ever since (January 1, 1944). A description and flow sheet of this mill have been published.6/ The mill has been operated to produce an average of about 50 short tons of concentrates a day which average 46 percent Cr_2O_3 and have a chromium-iron ratio of 2.65. Practically all the ore milled has been mined from the Grey Eagle and Black Diamond No. 11 claims.

ORE DEPOSITS

Twenty-five chromite deposits occur within the area mapped, but only eleven are promising enough to warrant detailed description. The deposits described are owned or leased by the Rustless Mining Corporation unless otherwise indicated.

Grey Eagle mine.—The largest known chromite deposit in Glenn County is at the Grey Eagle mine, which is situated at an altitude of about 2,600 feet on a spur of Red Mountain, in the northeast corner of sec. 25, T. 22 N., R. 7 W. (see pl. 2). The mine is served by a steep but graded road 2½ miles long and by a tram-line almost a mile long from the mine to the mill at Rustless. During World War I crude ore was mined from three large open pits and from an adit driven into the face of the northernmost pit (see pl. 3). Since 1918 extensive trenching, churn drilling, diamond drilling, and sectional-steel drilling have been employed to explore the deposit. At the present time, ore of milling grade is being mined from open pits.

The ore body is enclosed in a tabular mass of completely serpentinized dunite, which strikes approximately N. 30° E. and dips 25° to 60° NW. (see pls. 3 and 4). The dunite mass is exposed for about 750 feet along the strike but is cut off by a fault at each end, so that its total length is unknown. Diamond drilling by the U. S. Bureau of Mines has shown it to be about 100 feet in maximum thickness and about 325 feet in maximum width. It is surrounded by serpentinized saxonite, which encloses small masses of dunite, but as these do not contain concentrations of chromite they are not shown on the map.

As shown in plate 3, ore occurs along the entire length of the dunite; and this ore contains 10 percent or more of chromite. Diamond-drill cores indicate a maximum thickness of 50 feet and a maximum width of 260 feet for the ore body. The

6/ Huttl, J. B., California chrome assumes new importance: Eng. and Min. Jour., vol. 143, pp. 44-45, October 1942.

Reserves of chromite deposits in Glenn County, California
(Figures in short tons)
Estimates as of January 1, 1942

Mine or claim	Measured ore	Indicated ore	Inferred ore	Total	Average grade (percent Cr_2O_3)	Available chromite
Grey Eagle mine	107,715	32,305	33,800	173,820	12.9	44,810
Black Diamond mine	3,500	9,000	10,500	23,000	5-10	3,450
Black Diamond No. 2	10	250	......	260	5	26
Black Diamond No. 3	....	100	......	100	35	70
Black Diamond No. 4	5	70	......	75	40	60
Black Diamond No. 5	....	1,500	......	1,500	12	360
Black Diamond No. 6 and Loleta	50	......	......	50	12	12
Black Diamond No. 9	750	21,500	......	22,250	8	3,560
Black Diamond No. 10	....	600	......	600	16.4	200
Manzanita	....	......	1,000	1,000	10	200
Manzanita Extension	50	600	......	650	15	195
Hooligan	....	400	......	400	15	120
Boulder City	....	40	......	40	10	8
Katherine	....	......	1,500	1,500	12	360
Manzanita mine	....	......	......	....	....	......
Totals	112,080	66,365	46,800	225,245	13	53,431

shape, strike, and dip of the ore body roughly conform to those of the dunite, but contacts between ore and dunite are in general gradational and irregular. Throughout its length dunite lies above and below the ore body except at one place where the ore is faulted against saxonite.

The ore characteristically consists of fine-grained chromite evenly disseminated in a matrix of serpentine. The wide difference between the specific gravities of chromite and serpentine make this ore especially amenable to concentration. A subordinate amount of coarse-grained chromite occurs in clots, stringers, and lenses. Ore of this type at the southwestern end of the ore body contains kaemmererite and uvarovite. Other gangue minerals include magnesite, talc, and opal, all of which are present in minor quantities. In some places the ore has a distinct layered structure; the layers, which are discontinuous, differ widely in chromite content, some being nearly barren. The layers have the same general strike as the ore body but commonly have a lower dip.

Normal and reverse faults have broken the ore and the dunite bodies into a series of fault blocks, designated by numbers in plate 3. These blocks rise southward in a series of steps to the central part of the deposit, where two reverse faults bounding block 6 step down the southern part. These blocks south of block 6 again rise southward to blocks 13 and 14, which are stepped down by another reverse fault. Numerous minor faults further complicate the structural pattern. Approximately 400 feet south of the shear zone which cuts off the dunite and ore to the southeast, there is a sheared and brecciated zone more than 100 feet wide, which probably marks the largest displacement within the area. Although, because of inadequate exposures and the lack of markers for observing offsets, the faults can be traced for only short distances into the saxonite, it is probable that the saxonite also is much faulted.

Irregular masses of fine-grained diorite and thin, reeflike masses of hydrothermally altered peridotite are associated with some of the faults and shear zones.

The diamond-drilling program of the U. S. Bureau of Mines has provided enough data to delimit the extent of the ore body between the northern and southern faults. It seems unlikely that additional ore will be found southeast of the southern fault, as the faulting pattern indicates that this block moved upward, so that any ore it may originally have contained has probably been eroded away. At the northern end of the deposit the prospect is more encouraging. After the completion of the diamond-drilling program a narrow layer of ore was partly exposed in a road cut 275 feet east of diamond-drill hole AA. This ore has not been sufficiently exposed to be definitely correlated with the main ore body, but its layering has nearly the same dip as that in the main body, and the structural pattern is such that the ore in the cut and in the main body might be two faulted segments of a once continuous mass. The relations between ore, dunite, and saxonite in the road cut are similar to those observed at the upper edge of the ore body in blocks 3 and 13, and it is therefore possible that the ore will become thicker and better in grade with depth. No additional exploration in this area is contemplated, since it will be opened up in future mining operations.7/

The grade of the ore body varies considerably both along the strike and down the dip. The tenor of the ore is notably lower in blocks 4, 5, and 6 (pl. 3) than in the blocks to the northeast and southwest, and the ore in the southwestern blocks is generally of somewhat higher grade than that in the northeastern blocks. The weighted average for more than 350 assays, some by the U. S. Bureau of Mines and some by the Rustless Mining Corporation, of samples from all parts of the ore body is approximately 15 percent Cr_2O_3. Initial mining indicates, however, that the actual grade is several percent higher. The analyses of chromite given in figure 1 and in the table on page 9 are believed to be representative of the ore body. On the basis of estimated mining and milling costs and a fixed scale of prices for concentrates stipulated in a contract with the Metals Reserve Co., the cut-off grade is approximately 5 percent Cr_2O_3. Calculated reserves for each block of ore are given in the table below. An average grade is computed for each block, and the number of cubic feet of ore to the ton was calculated from the measured specific gravities of samples representing approximately the average grade of each block.

Reserves of the Grey Eagle chromite deposit 1/

Ore block	Average percent Cr_2O_3	Approximate number of cu. ft. per short ton	Reserves in short tons 2/			
			Measured ore	Indicated ore	Inferred ore	Total
1 and 2	13.71	11.7	18,975	6,325	......	25,300
3	13.51	11.7	30,130	8,800	15,500	54,430
4	6.99	12.5	14,400	9,600	......	24,000
5	6.10	12.5	8,100	4,800	10,200	23,100
6	5.81	12.5	......	.....	720	720
7	12.94	11.8	7,120	.....	1,780	8,900
8	15.68	11.5	11,250	1,150	1,550	13,950
9	24.14	10.5	450	.....	......	450
10	24.28	10.5	3,575	.....	3,575	7,150
11	20.98	11.0	1,090	730	200	2,020
12	37.88	9.2	275	.....	275	550
13	20.15	11.0	10,700	.....	......	10,700
14	21.09	11.0	1,650	900	......	2,550
Totals................			107,715	32,305	33,800	*173,820

1/ Published with permission of the Rustless Mining Corporation.
2/ Calculated as of January 1, 1942.
* On January 1, 1944, the Rustless Mining Corporation reported total ore mined 143,318 short tons, estimated reserves on Grey Eagle and Black Diamond No. 11 claims 8,563 short tons, or a total of 151,881 short tons. This compares favorably with the above estimate of measured and indicated ore of 140,020 short tons. The average grade of the ore mined has been 13 percent.

Black Diamond mine.—The Black Diamond mine is in the NW¼ of sec. 25, T. 22 N., R. 7 W., at an altitude of 3,250 feet, and is about a mile by road from the upper terminal of the Grey Eagle tram-line (see pl. 2). Development work at the mine

7/ Mining operations carried on during 1942 and 1943 have largely verified these conclusions. No ore has been found south of the southern fault. Bulldozing and sectional-steel drilling on the northern end of the deposit proved that the layer of ore extended less than 2 feet in depth and had an areal extent of less than 50 square feet. The enveloping dunite extended only a few feet beyond the ore.

consists of a large open cut, and a number of small open cuts and shallow trenches. The trenching was done as part of a sampling program by the U. S. Bureau of Mines, which also made an unsuccessful attempt to reopen an old adit driven westward from the large open cut.

The principal geological features of the mine are two northwestward-dipping zones of chromite ore (pl. 5) in northwestward-dipping masses of dunite, which are enclosed by saxonite. Both rocks are partly serpentinized.

The lower zone, well exposed in the large open cut, dips 20° to 30° northwestward and has a maximum thickness of 25 feet. The ore consists of fine-grained chromite disseminated in dunite and of stringers, small pods, and clusters of nodules of coarse-grained chromite. A normal fault dipping about 60° NE. truncates the dunite and ore along the northeast wall of the cut. Dunite and ore exposed in trenches east of the cut are believed to be offset from the main zone; if so this ore may be thicker at depth, and extend farther northeast, than surface exposures indicate.

If an average thickness of 15 feet, a length of 120 feet, a width of 50 feet, and 10 cubic feet per ton of ore are assumed, it is estimated that the indicated ore southwest of the fault amounts to 9,000 short tons. Reserves northeast of the fault can only be inferred at present, but it is believed that they may possibly amount to 2,000 short tons. The ore in the lower zone is thought to contain about 10 percent of Cr_2O_3.

Exploration of the lower zone could best be accomplished by sectional-steel drilling northwest and northeast of the cut.

The upper zone is irregular and ill-defined but ore is found along the strike for a distance of about 550 feet. The dunite mass enclosing the ore is irregular in shape, and its maximum thickness is probably not more than 20 or 25 feet. Although several feet of dunite usually separate the ore from saxonite, ore occurs at several places within a few inches of the saxonite. The ore is similar to that of the lower deposit, and its maximum thickness is about 15 feet. The dip of the layering in the ore and the correlation from one sectional-steel drill hole indicate a northwestward dip of 40° to 50°. Bulldozer trenching along the outcrop of the upper zone has shown the ore to be discontinuous. Part of this discontinuity is due to offsetting by many small cross-faults, but in addition the ore apparently occurs as a number of isolated chromite-rich bodies scattered through dunite, and the bodies at the ends of the zones are smaller, leaner, and more scattered than those near the center.

The lowest ore exposed at the ends of this upper zone is at approximately the same altitude at both ends; near the middle a sectional-steel drill hole penetrated good ore down to a point only 20 feet higher than the exposures at the ends of the zone. It therefore seems safe to assume that ore extends to this depth throughout the length of the zone.

Assuming an average thickness of 4 feet, a length of 500 feet, a dip of 45° and 10 cubic feet of ore per ton, total reserves of about 10,000 short tons of indicated ore containing 5 to 10 percent Cr_2O_3 can be inferred for the upper zone.8/

8/ Estimated from assays by the U. S. Bureau of Mines and the Rustless Mining Corporation.

The estimate would be increased by 200 tons with each proved additional foot of depth down the dip.

Because of the low grade and narrow widths of the ore, it is likely that only that ore which can be mined cheaply from the surface will be extracted. The operators have explored the central part of the zone for about 200 feet along its strike by means of drill holes to a depth of 18 feet. This work has proved reserves of about 1,500 short tons of ore containing 5 to 10 percent of Cr_2O_3. Extraction of this ore by surface operations will necessitate the removal of about 20 tons of waste for each ton of ore mined. The operators plan to explore the zone to greater depths by sectional-steel drilling.

The dumps of the large open cut are estimated to contain about 6,000 short tons of material, of which perhaps 2,000 short tons could be profitably milled.

The total estimated reserves in the Black Diamond mine thus amount to 23,000 short tons of ore containing 5 to 10 percent Cr_2O_3.

Black Diamond No. 9 mine.—The Black Diamond No. 9 mine is on the crest of Manzanita Ridge, in the SE¼ sec. 14, T. 22 N., R. 7 W., about 3 miles by trail from Rustless (see pl. 2). An old road 3½ miles long from the mine to the Conklin Ranch in Tehama County is now impassable. Development at the mine consists of one large and four small open cuts and four shallow trenches.

The mine workings expose three zones of low-grade disseminated chromite ore in serpentinized dunite (see fig. 2). The largest of these zones is exposed in the large open cut and on both sides of it over a total length of about 150 feet and an average width of 15 feet. The attitude of the layering in the ore indicates that the zone strikes a few degrees east of north and dips about 60° W. The ore is estimated to contain 7 to 10 percent Cr_2O_3. The second zone, which is similar to the first in grade and attitude, crops out 30 feet farther to the east. It is traceable for about 120 feet and has a maximum thickness of 6 feet. The third zone, which is east of the second zone, is only about 1 foot thick and 30 feet long but is estimated to contain 20 or 25 percent Cr_2O_3.

The southern ends of the two larger zones are terminated by a fault that strikes N. 55° W. Small masses of diorite crop out along the south side of the fault, and ore has been exposed in two small cuts south of the fault. The ore is badly sheared, and its attitude and extent are obscure, but it seems to represent an offset continuation of the ore north of the fault.

The three zones north of the fault, on the assumption that they extend 75, 50, and 15 feet respectively down the dip, are estimated to contain 20,500 short tons of indicated ore averaging 7 to 10 percent Cr_2O_3. South of the fault there is probably at least 1,000 short tons of ore, and the dumps contain about 1,500 short tons of material, half of which could perhaps be profitably milled.

Future exploration and development of the mine requires the construction of a road, 4½ miles long, from Rustless. Such a road would also serve other deposits located on Manzanita Ridge. Until the road is constructed, exploration will be limited to trenching and sampling, but when equipment can be transported to the mine, the deposit should be tested by a series of sectional-steel drill holes located west of the ore zones on each side of the fault.

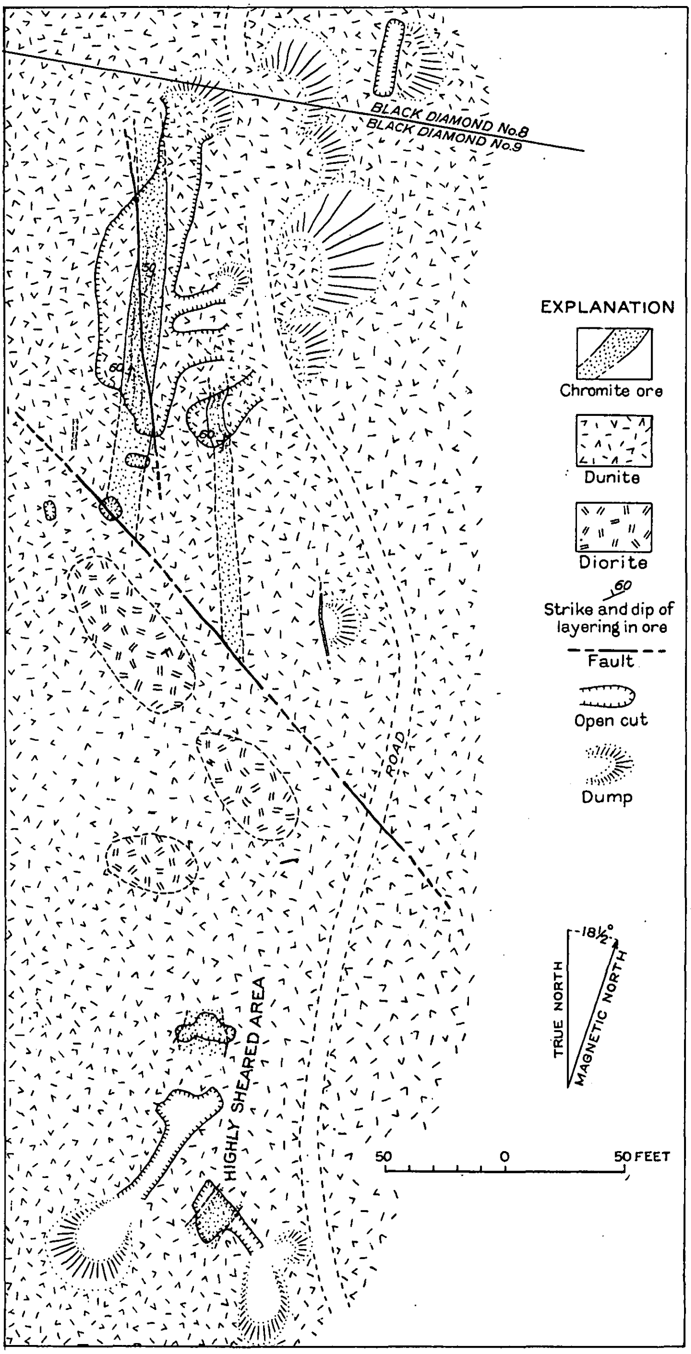


Figure 2.—Geologic map of the Black Diamond No. 9 mine. Base surveyed by Rustless Mining Corporation.

Black Diamond No. 10 claim.—The Black Diamond No. 10 deposit is on the north side of Manzanita Ridge, about 1,200 feet southeast of the Black Diamond No. 9 mine. Development on the property consists of two small open cuts and two small trenches (see pl. 6).

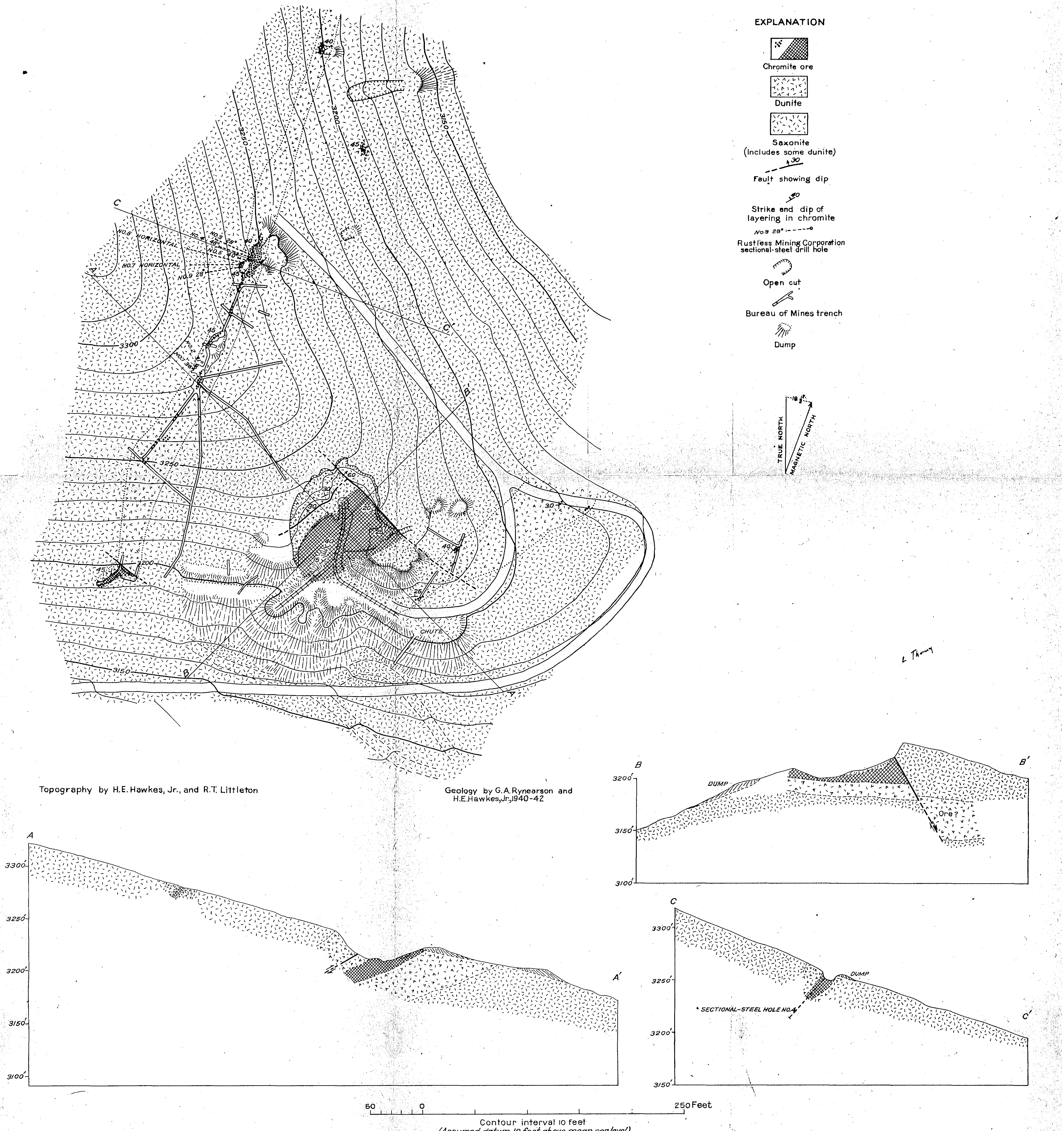
The ore consists of imperfectly formed nodules of chromite and of fine-grained disseminated chromite. An ore body 12 feet thick and 25 feet long is exposed in the upper cut. Layering in this ore indicates that the ore body strikes N. 70° E. and dips 20° to 25° SE. An exposure of ore, about 5 feet wide and 15 feet long, is visible in the lower cut. The ore in both cuts is apparently part of a single ore body, offset by a steeply dipping fault that strikes N. 70° E.

A channel sample cut from the face of the upper cut assayed 16.4 percent Cr_2O_3. The complete analysis of this sample appears in the table on page 9. Reserves of 600 short tons of ore are indicated, and it is unlikely that exploration would reveal much more. If sectional-steel drilling equipment is used at the Black Diamond No. 9 mine, several holes should be drilled on the No. 10 claim to determine the depth to which the ore extends.

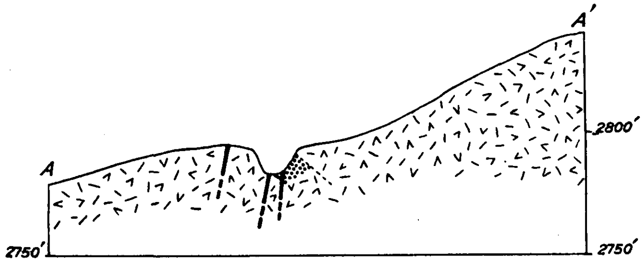
Black Diamond No. 5 claim.—The Black Diamond No. 5 claim, formerly known as the Sunnyside Chrome claim, is on the north side of Heifer Camp Creek, near the western edge of sec. 19, T. 22 N., R. 6 W. In 1918 this claim yielded 18 long tons of crude ore containing 50 percent Cr_2O_3. Its workings comprise a large open cut and a short adit. The ore zone, consisting of layers of chromite disseminated in dunite, strikes N. 77° E. and dips about 20° N. It is traceable for 140 feet in the face of the cut and appears to be terminated by faults at both ends. Near the middle of the cut the zone is 8 to 10 feet thick, but the layers of ore are separated by as much as 3 feet of barren dunite, and at each end of the zone the ore is only about 1 foot thick. By selective mining, an aggregate thickness of 3 feet of ore, estimated to contain 25 to 30 percent chromite, could be recovered. Assuming an average thickness of 3 feet, a tapering width equal to half the length, and 10 cubic feet per ton of ore, reserves of 1,500 short tons of indicated ore are estimated to be present.

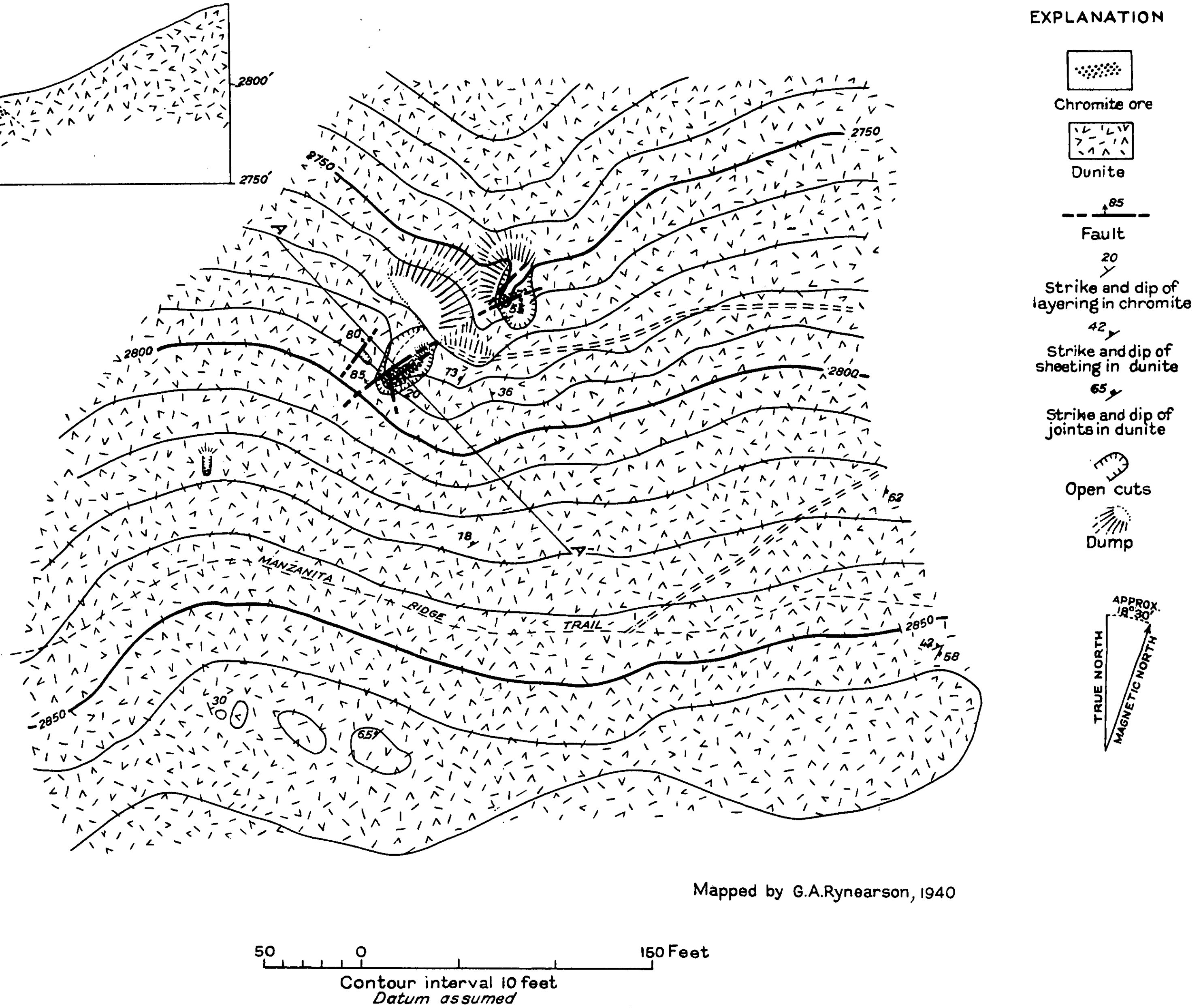
Black Diamond No. 6 and Loleta (K. I. Cooper) claims.—The Black Diamond No. 6, formerly known as the Daisy, and the Loleta claims are in the SW¼ sec. 24, T. 22 N., R. 7 W. In 1918 these claims yielded 44 long tons of crude ore containing 50 percent Cr_2O_3. The claims are developed by twelve small prospect pits in ore, but these are partly caved and the extent of the ore is concealed. The ore consists of fine-grained disseminated chromite and stringers of coarse-grained chromite in two nearly parallel zones of dunite, which strike about N. 40° E. It is doubtful whether ore is continuous between the prospect pits in either zone. There are measurable reserves of 50 short tons of ore containing 20 to 30 percent Cr_2O_3. The total reserves are undoubtedly much larger, but they cannot be estimated at the present stage of development.

Manzanita claim (F. M. Burrows).—The Manzanita claim—not to be confused with the Manzanita mine—is in the NW¼ sec. 19, T. 22 N., R. 6 W. It is developed by two groups of prospect pits, but many of these pits are caved, and heavy float obscures much of the geology. Several feet of good disseminated ore may be seen in three pits of each group. If these exposures represent two continuous ore zones, several thousand tons of milling ore may be developed on the claim; but



GEOLOGIC MAP AND SECTIONS OF THE BLACK DIAMOND MINE





GEOLOGIC MAP AND SECTION OF THE BLACK DIAMOND NO. 10 CLAIM considerable trenching, preferably by a bulldozer, must be done before an estimate of reserves can be made.

Manzanita Extension claim (Lena Burrows).—The ore body on the Manzanita Extension claim, about 1,200 feet northwest of the Manzanita claim, has been prospected by two parallel open cuts and three shallow trenches. Disseminated ore, which strikes N. 78° E. and dips 33° N., has been exposed for 100 feet and shown to be at least 4 feet thick. Reserves of approximately 650 short tons of ore containing about 15 percent Cr_2O_3 are indicated. Removal of heavy float from the eastern

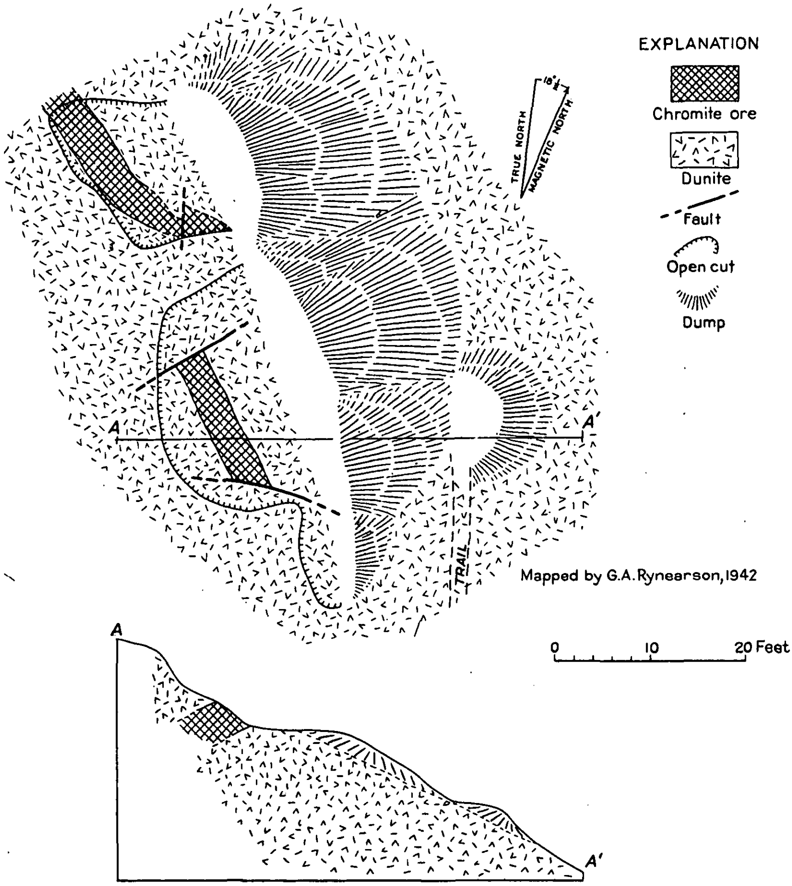


Figure 3.—Geologic sketch map of the Hooligan deposit.

end of the deposit to determine the actual length of the ore body and sectional-steel drilling to determine the depth may prove the reserves to be more than double the above estimate.

Hooligan deposit (F. M. Burrows).—Chromite is exposed in two open cuts on the Hooligan deposit, near the southern boundary of sec. 13, T. 22 N., R. 7 W. (fig. 3). The ore body, which has been uncovered for 50 feet and has a maximum thickness of 5 feet, consists of fine-grained chromite disseminated in the dunite country rock. About one-third of the ore is estimated to contain 30 percent Cr_2O_3, but the average for the entire deposit is probably about 15 percent. Reserves of not more than 400 short tons of ore are indicated.

Katherine claim.—The Katherine claim, in the SE¼ sec. 24, T. 22 N., R. 7 W., includes an unprospected deposit of good disseminated ore. Although talus obscures most of the ore body, the ore is probably continuous for at least 100 feet and maintains a thickness of about 3 feet. Reserves are estimated from present showings to be approximately 1,500 short tons of inferred ore, containing about 25 to 30 percent chromite, but exploration might justify a materially higher estimate.

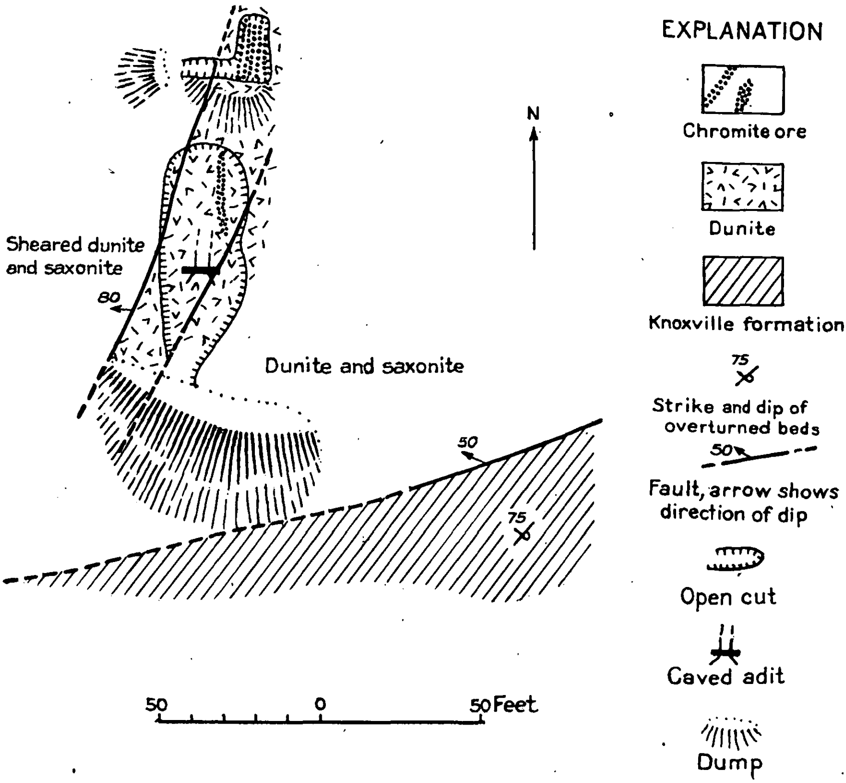


Figure 4.--Geologic sketch map of the Manzanita mine.

Manzanita mine.—The Manzanita mine—not to be confused with the Manzanita claim—is on the Cushman ranch, about 250 feet north of Watson Creek, in the NE¼ sec. 31, T. 22 N., R. 6 W. Its workings consist of two open cuts, which are badly caved (fig. 4). According to Ed Howard of Elk Creek, an adit was driven 50 feet into the face of the lower cut, and a shaft 25 feet deep was sunk at the end of the adit. The portal of the adit is now caved. The mine yielded 79 long tons of crude ore in 1917. The present condition of the workings does not permit a reliable estimate of reserves, but geologic evidence indicates that more than 1,000 tons of milling-grade ore might possibly be developed.