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CHROMITE DEPOSITS OF THE EASTERN PART OF THE STILLWATER COMPLEX STILLWATER COUNTY, MONTANA

BY
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CHROMITE DEPOSITS OF THE EASTERN PART

OF THE STILLWATER COMPLEX, STILLWATER COUNTY, MONTANA

By J. W. Peoples and A. L. Howland

ABSTRACT

Chromite has been known for some years to occur in a belt of ultramafic rocks, composed chiefly of pyroxene and olivine, 27 miles long on the northeastern margin of the Beartooth Mountains, in Stillwater and Sweetgrass Counties, Mont. The outcrop of these igneous rocks, which form the lower part of the layered Stillwater complex, ranges in width from a quarter of a mile to a mile. Chromite occurs near the center of it in layers and lenses, parallel to the layering of the complex, throughout most of the length of the belt.

In 1939 a Geological Survey party made a detailed study of the chromite deposits on the so-called Benbow claims, of the Chromium Products Corporation, on Little Rocky Creek, and a brief reconnaissance of the deposits on the west side of Stillwater Canyon. Trenching on the Benbow claims by the Bureau of Mines made it possible to trace segments of a tabular body of chrome ore with an aggregate length of 5,660 feet in a distance of 9,000 feet along the strike. The discontinuity is due in part to offsets on small faults approximately at right angles to the strike and in part to the occurrence of chromite in overlapping lenses. The average width of the ore is 5 to 7 feet, but on the eastern end of the claims a strip of disseminated ore 430 feet in length averages 29½ feet in width. As all the ore is approximately half chromite, it will need to be concentrated.

Considering the ore as proved for 50 feet below the mapped outcrop, the authors estimate the presence of 200,000 short tons of ore. The possible tonnage of ore above the Eclipse adit--the lowest opening on the property--is calculated to be nearly 1,500,000 short tons of massive ore and 345,000 tons of disseminated ore. The chromite horizon at each end of the property is covered, but geologic evidence strongly implies that it continues. On the west side of Stillwater Canyon chromite-rich bands of varying thickness alternate with bands of rock containing disseminated chromite for a distance of about 1,200 feet along the strike. Available data are insufficient for an estimate of tonnage, but the area appears promising for development of a large tonnage of millable ore.

Although no high-grade ore is to be expected, it is clear from this study of a small part of the Stillwater complex that a large tonnage of submarginal ore can be recovered in time of need.

INTRODUCTION

The Stillwater complex of igneous rocks is exposed in a belt 1 to 5 miles wide and 30 miles long on the northern margin of the Beartooth Mountains in Stillwater, Sweetgrass, and Park Counties, Mont. (fig. 50). This complex, which contains a chromite-bearing zone, is composed of anorthositic, noritic, and ultramafic (pyroxene-olivine) rocks. Although it is known that chromite occurs more or less continuously for 27 miles,

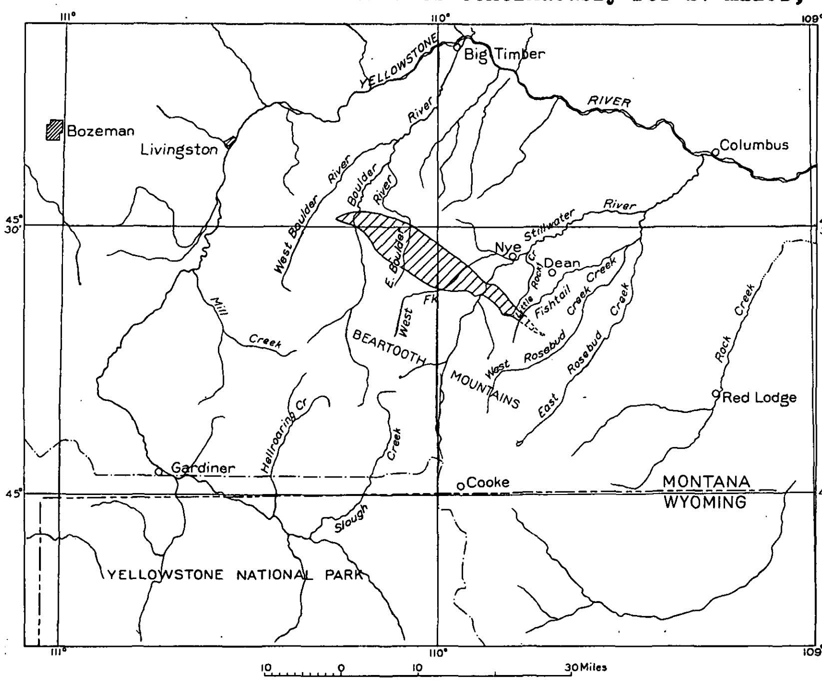

Figure 50.--Index map of Montana. Ruled area shows location of Stillwater complex.

the field work on which this report is based was confined to the deposits near the east end of the complex, between latitudes 109°45' and 109° 55'.

The Beartooth Mountains, a dissected mountain upland, range in altitude from 9,000 to 12,000 feet and are cut by canyons from 3,000 to 5,000 feet deep. Automobile roads from Big Timber up the Boulder River and from Columbus up the Stillwater

River give relatively easy access to two places in the chromite-bearing belt, but elsewhere transportation is difficult. The Benbow camp, on Little Rocky Creek, used in 1939 as field camp, can be reached by rough wagon road from Dean, 9 miles away. Dean itself is 32 miles from Columbus, the nearest point on the railroad.

History

The war demand of 1917 and 1918 stimulated the search for chromite in all parts of the country, and in those years three properties in the Stillwater region were actively developed. No shipments were made, however, and when the war demand ceased there was very little further development except at the eastern end of the belt, where some improvements were made on the seven claims of the late T. C. Benbow. A wagon road from this property to Dean was built, three adits, one of them 500 feet long, were driven, and several trenches were dug. Three cabins were built, an air compressor was installed, and in 1929 the camp was prepared for mining; but the work ceased because of the financial uncertainties of that year. On November 24, 1933, a patent on these seven claims was issued. The property is now owned by the Chromium Products Corporation, of Livingston, Mont.

Previous work

In 1918 Westgate [1/] made a reconnaissance study of the chromite deposits of the Beartooth Mountains. Bevan [2/] has described the general geology and physiography of the region. A group from Princeton University began field work there in 1930,

1/ Westgate, L. G., Deposits of chromite in Stillwater and Sweet Grass Counties, Mont.: U. S. Geol. Survey Bull. 725, pp. 67-84, 1921.

2/ Bevan, Arthur, Summary of the geology of the Beartooth Mountains, Montana: Jour. Geology, vol. 31, pp. 441-465, 1923; Rocky Mountain peneplains northeast of Yellowstone Park: Jour. Geology, vol. 33, pp. 563-587, 1925.

and the writers, as members of that group, spent several seasons studying the Stillwater complex. Edward Sampson, who directed the field work, studied the chromite deposits, and H. H. Hess is making a detailed study of the mineralogical problems. These two men and the present writers have a detailed report on the geology of the complex in preparation. A general summary, several abstracts, and a few special papers have been published.[3/] Vhay[4/] has studied the structure of the mountain front adjacent to the complex.

In 1935 Schafer[5/] mapped the chromite of the Stillwater complex on the scale of 1 to 62,500 for the Montana Bureau of Mines and Geology. He refers to unpublished private reports[6/] made by several consulting engineers and geologists for mining companies.

Field work and acknowledgments

The present report is based on 5 weeks of field study during August and September 1939. In this work the authors were assisted by R. K. Doten, J. C. Bogert, and W. R. Jones. The

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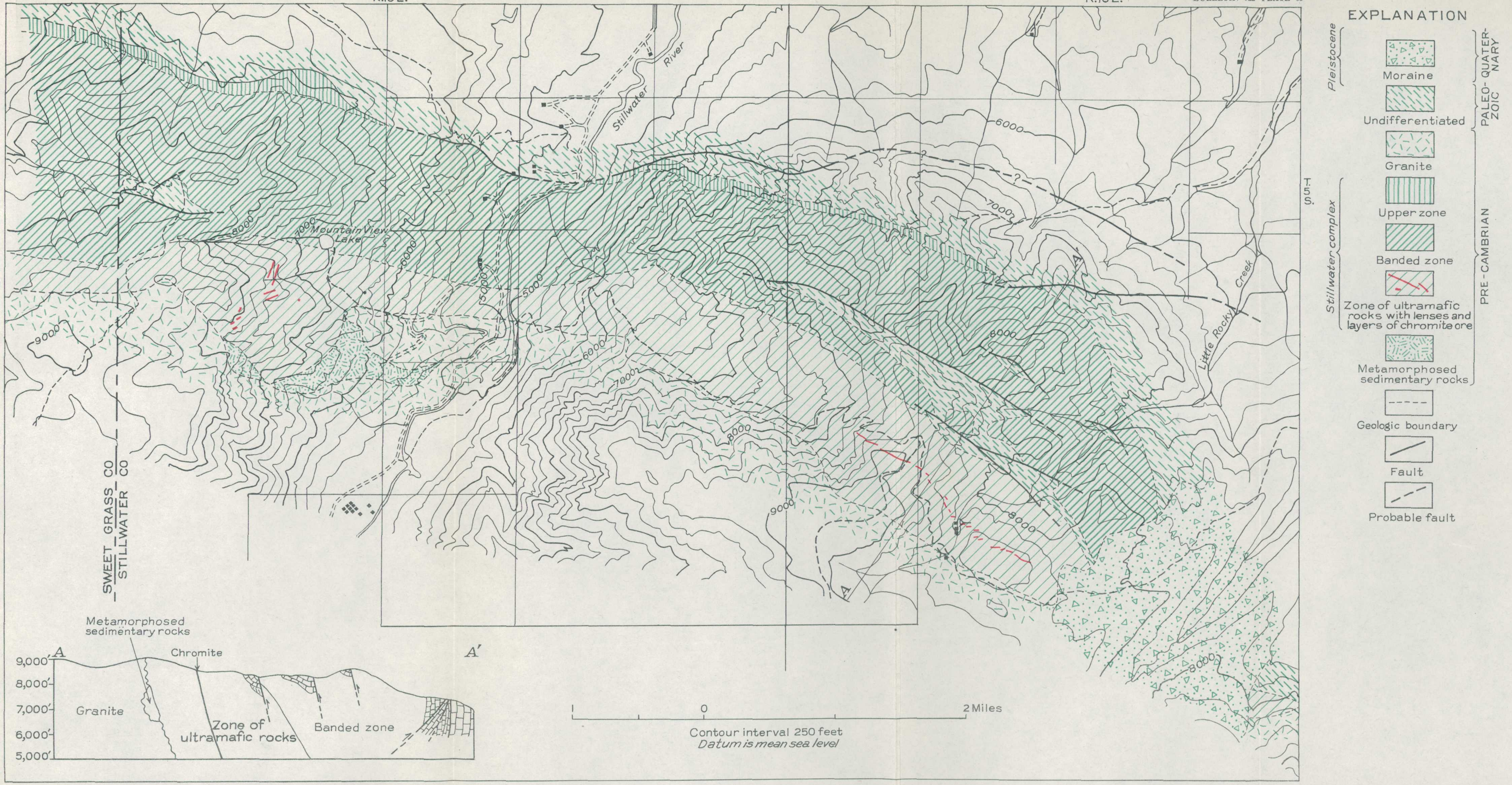
3/ Peoples, J. W., The Stillwater igneous complex, Montana [abstract]: Am. Mineralogist, vol. 18, p. 117, 1933. Hess, H. H., Plagioclase, pyroxene, and olivine variation in the Stillwater complex [Montana] [abstract]: Am. Mineralogist, vol. 21, pp. 198-199, 1935. Peoples, J. W., Gravity stratification as a criterion in the interpretation of the structure of the Stillwater complex, Montana: 16th Internat. Geol. Cong. [1933] Rept., vol. 1, pp. 353-360, 1936. Howland, A. L., Peoples, J. W., and Sampson, Edward, The Stillwater igneous complex and associated occurrences of nickel and platinum-group metals: Montana Bur. Mines and Geology Misc. Contr. 7, v. 15 pp., 1936. Hess, H. H., Primary banding in norite and gabbro: Am. Geophys. Union Trans., pt. 1, pp. 264-268, 1938; A primary peridotite magma: Am. Jour. Sci., vol. 35, pp. 321-344, 1938. Hess, H.H. and Phillips, A. H., Orthopyroxenes of the Bushveld type: Am. Mineralogist, vol. 23, pp. 450-456, 1938. Hess, H. H., Extreme fractional crystallization of a basaltic magma: The Stillwater igneous complex: Am. Geophys. Union Trans., Pt. 3, pp. 430-432, 1939. Peoples, J. W., The Stillwater igneous complex, Montana: New York Acad. Sci. Trans., ser. 2, vol. 1, no. 7, pp. 107-109, 1939. Hess, H. H., and Phillips, A. H., Optical properties and chemical composition of magnesian orthopyroxenes: Am. Mineralogist, vol. 25, pp. 271-285, 1940.

4/ Vhay, J. S., The geology of a part of the Beartooth Mountain front near Nye, Mont.: Unpublished dissertation at Princeton University, 1934.

5/ Schafer, P. A., Chromite deposits of Montana: Montana Bur. Mines and Geology Mem. 18, v. 35 pp., 1937.

6/ Idem, p. 2.



GEOLOGIC MAP OF THE EASTERN PART OF THE STILLWATER COMPLEX, STILLWATER COUNTY, MONTANA.

chromite was mapped with plane table and telescopic alidade from its easternmost exposure for about 9,000 feet westward along the strike, on a scale of 200 feet to the inch, and some reconnaissance work was done on the west slope of the Stillwater Valley. The field party camped with a Bureau of Mines party, which, under the direction of P. T. Allsman, trenched and sampled the chromite at 50-foot intervals along the strike. Although the two parties worked separately, their work was coordinated in every way possible, and the writers are grateful to Mr. Allsman and his party for their splendid cooperation.

A topographic party under the direction of C. A. Stonesifer was mapping the Nye No. 2 quadrangle (long. 109°45' to 110°00' and lat. 45°15' to 45°30') in 1939. A photostat copy of their plane-table sheet was used as a base for the general map shown in plate 63. The detailed map (pl. 64) was tied in with points previously located by topographers.

The writers are indebted to B. E. Berg, of Livingston, H. G. McClain, of Columbus, C. G. Rich, of Dean, and M. W. Mouat, of Nye, for their many courtesies to the party.

OUTLINE OF GEOLOGY

Geologically the Beartooth Range may be described as a huge asymmetrical east-west anticline, whose core of pre-Cambrian granitic and metamorphic rocks is bordered on the north by sharply upturned Paleozoic and Mesozoic sedimentary rocks. From the Stillwater River to Red Lodge the edge of the mountain front is marked by thrust faults dipping southward. For 30 miles along the edge of the dissected upland a belt of layered ultramafic igneous rocks, composed chiefly of olivine and pyroxene, from 1 to 5 miles wide lies between the upturned Paleozoic beds to the north and granite and ancient metamorphosed sedimentary rocks to the south. This series of layered igneous rocks has been named the Stillwater complex.[7] It is subdivided as shown in table 1. The chromite deposits discussed in this report occur about midway between the top and bottom horizons of the zone of ultramafic rocks. This zone was referred to previously by the writers[8] as the ultrabasic zone and was called a pyroxenite dike by Westgate.[9] The layers of the complex are believed to have been nearly horizontal when formed,[10] but in the eastern part they now dip from 60° S. to 60° N.

The detailed mapping (see pl. 64) in 1939 was restricted to the ultramafic zone. Plate 63, which shows the geology of the Stillwater complex from the Stillwater-West Stillwater divide to Fishtail Creek, is based largely on the previous work of the writers. The mapping of the Paleozoic rocks is generalized from an unpublished map by Vhay.[11]

PRE-CAMBRIAN ROCKS

Ancient sedimentary rocks

Sedimentary rocks, much altered by the intrusion of the Stillwater complex, are found south of the complex on the west side of Stillwater Canyon and as scattered inclusions in the granite east of the canyon. The rocks include dense gray hornfels, an iron formation, and light-colored quartzite. The hornfels is very fine grained and looks in hand specimen like a dark quartzite or a fine-grained basaltic rock. This series

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7/ Peoples, J. W., The Stillwater igneous complex, Montana [abstract]: Am. Mineralogist, vol. 18, p. 117, 1933.
8/ Howland, A. L., Peoples, J. W., and Sampson, Edward, op.cit., p. 8.
9/ Westgate, L. G., op. cit., p. 68.
10/ Peoples, J. W., Gravity stratification as a criterion in the interpretation of the structure of the Stillwater complex, Montana: 16th Internat. Geol. Cong. [1933] Rept., vol. 1, pp. 353-360, 1936.
11/ Vhay, J. S., op. cit.

is believed to have formed the floor along which the Stillwater complex was intruded.[12/]

Stillwater complex

Basal zone

A thin layer at the base of the complex consists of diabasic norite, which is a medium-grained rock, gray on the fresh surface but brown on the weathered surface. It commonly contains grains and patches of pyrrhotite and chalcopyrite and in its exposure along the south side of Nye Basin is reddish-brown because of the oxidizing of pods and disseminated grains of sulfides. It is not easily distinguished from the hornfels that is in contact with it in the Stillwater Canyon. The nickel-copper sulfide deposits on the property of M. W. Mouat on the west side of the Stillwater Valley are partly in this layer and partly in the hornfels below.[13/]

Ultramafic zone

The layer second from the base consists of rocks that are almost exclusively made up of minerals rich in magnesium and iron. Plagioclase feldspar is commonly present, although nowhere in excess of 15 percent by volume, and green diopside occurs locally, but the dominant primary minerals are an orthorhombic pyroxene and olivine. On the west slope of Stillwater Canyon all the rocks are remarkably fresh, but east of Stillwater River the olivine is extensively altered to serpentine, and in places, especially in the lower part of the zone, pyroxene also is serpentinized.

12/ Howland, A. L., Sulphides and metamorphic rocks at the base of the Stillwater complex: Unpublished dissertation for the degree of Doctor of Philosophy, Princeton University, 1933.

13/ Howland, A. L., Peoples, J. W., and Sampson, Edward, op. cit.,p.10.

Table 1.--Stillwater complex [1/]

Zones	Thickness (feet)	Character	Metalliferous deposits
Upper zone.	800-6,000	Gray, white, and spotted igneous rocks (anorthosite, norite, gabbro).	Disseminated sulfides at one or two horizons.
Banded zone.	3,700-7,350	Gray or brown norite and bands of white or gray anorthosite. Spotted troctolite (olivine gabbro).	At least two bands containing small percentages of sulfides with a little platinum and palladium.
Ultramafic zone.	1,850-4,000	Olivine and pyroxene in various proportions form pyroxenite (variety bronzitite), harzburgite, and dunite, all dark, heavy rocks.	Chromite bands with harzburgite near the middle of the zone.
Basal zone.	0-200	Diabasic norite........	Locally chalcopyrite and pentlandite-bearing pyrrhotite.

1/ Length of complex 30 miles; width of outcrop 1 to 5 miles; area 70 square miles; thickness 16,000 feet. Top of complex is eroded.

The ultramafic zone contains rocks composed essentially of pyroxene, rocks composed essentially of olivine, and rocks that contain these minerals in almost every intermediate proportion. In this paper a rock containing 90 percent or more of pyroxene is called pyroxenite, one containing 90 percent or more of olivine is called peridotite, and any rock of intermediate composition is called harzburgite.

The principal rock types of this zone are bronzitite (a variety of pyroxenite), granular and poikilitic harzburgite, and basic pegmatites.

Bronzitite.--Bronzitite is composed essentially of the orthorhombic pyroxene bronzite, the chemical and optical properties of which have been described by Hess and Phillips.[14/] The

14/ Hess, H. H., and Phillips, A. H., Orthopyroxenes of the Bushveld type: Am. Mineralogist, vol. 23, pp. 450-456, 1938; Optical properties and chemical composition of magnesian orthopyroxenes: Am. Mineralogist, vol. 25, pp. 271-285, 1940.

rock is coarse-grained and greenish brown on fresh fracture but a deep reddish brown on the weathered surface. It is massive and exceptionally tough because of the interlocking of the bronzite crystals. In places white plagioclase (bytownite) fills the spaces between the bronzite crystals. Bronzitite occurs both north and south of the chromite horizon, but the northern, or upper, bronzitite can usually be distinguished by the presence of a green monoclinic pyroxene, diopside, in skeleton crystals whose maximum diameter is 3 inches. Although chromite is very scarce in the bronzitite, thin seams from 1 to 2 inches thick have been seen at a contact between bronzitite and harzburgite.

Granular harzburgite.--The granular harzburgite is somewhat similar to the bronzitite but contains an appreciable amount of olivine. The olivine is not conspicuous, but on fresh surfaces it may be distinguished from the bronzite by its lack of good cleavage and by its more or less advanced alteration to dark greenish-black serpentine. It is more easily recognized on the weathered surface, where the olivine and serpentine weather more rapidly than the bronzite, so that the rock has a pitted appearance. A little white plagioclase feldspar is usually present between the grains of bronzite. Chromite is locally present as an accessory but in very small amounts.

Poikilitic harzburgite.--The poikilitic harzburgite differs little from the granular in composition, though it usually contains a larger proportion of olivine and serpentine. Its distinctive features are textural. The bronzite occurs in skeleton, or poikilitic, crystals containing rounded grains of altered olivine. Most of the poikilitic crystals range in diameter from 1 inch to 6 inches, but crystals as much as 12 inches in diameter have been seen in the western end of the complex. On a sunny day it is easy to recognize this rock, as the large bronzite crystals reflect light from their cleavage faces; the enclosed olivine grains are dull. Much of the rock is altered to serpentine, but even where the bronzite is altered to serpentine its cleavage is still visible. Some interstitial altered plagioclase is usually present, and black chromite grains are enclosed in the plagioclase or the bronzite. Poikilitic harzburgite occurs on both sides of the chromite seam, and in places it merges gradually into an almost solid chromite ore. (See fig. 51.)

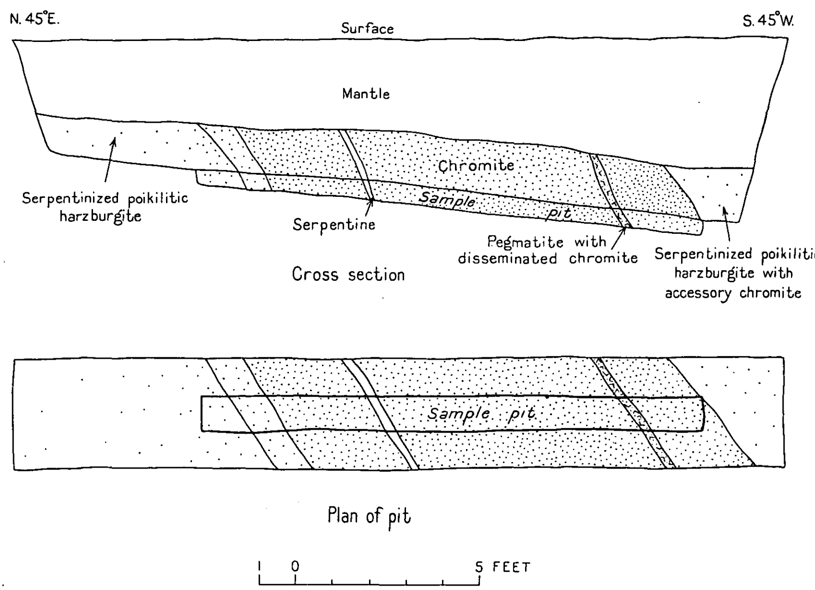

Figure 51.--Plan and cross section of pit D-32, Big Seven claim.

Basic pegmatites.--Irregular bodies of a rock of coarse and irregular texture occur at several places, but they are most common near the chromite horizon. (See figs. 52 and 53.) They contain the same minerals as the other rocks of the ultramafic zone--olivine, orthorhombic pyroxene, plagioclase, and diopside; the latter two are almost invariably present even where they are absent from the surrounding rock. These pegmatites usually contain chromite.

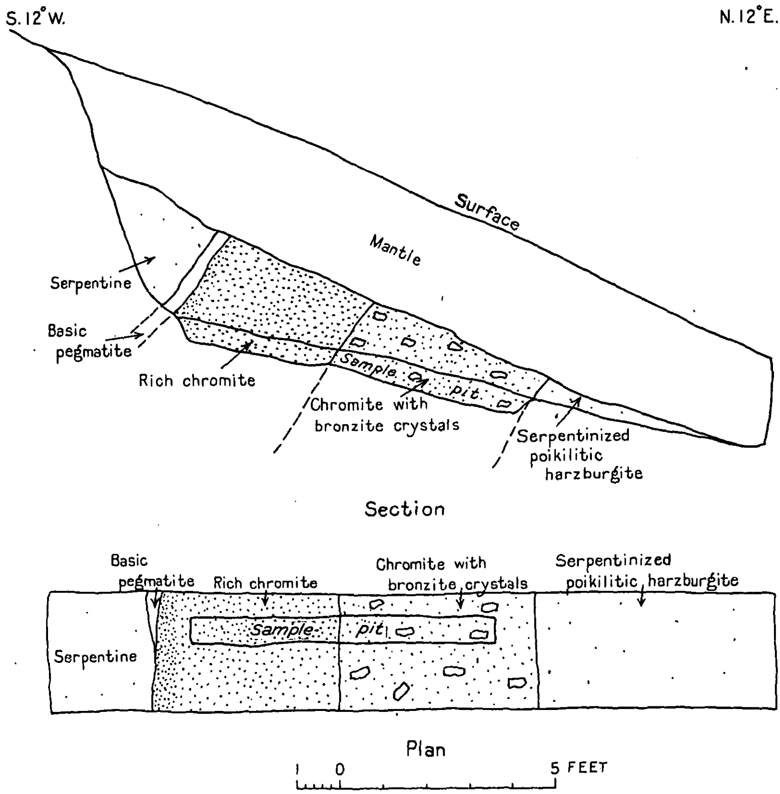

Figure 52.--Plan and cross section of pit D-6, Majestic claim.

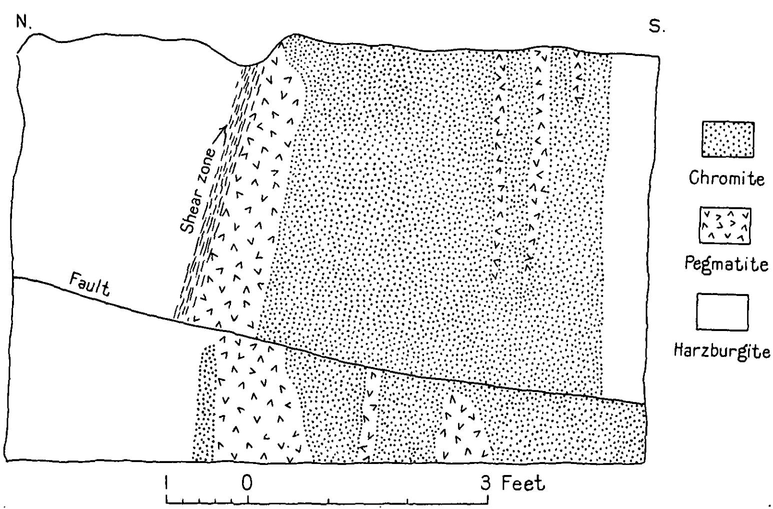

Figure 53.--Sketch of east wall of discovery pit (A-1), Lucky Strike claim. Shows characteristic pegmatite streaks and patches in the chromite. The fault dips 62° E.

Basic dikes

At the face of the Eclipse adit a much-fractured, green, fine-grained rock of gabbroic or dioritic composition is exposed. Although its contacts were not seen, this rock is regarded as a dike cutting the complex, and its probable extension at the surface is mapped approximately from float on the steep hillside above the Benbow camp. Dikes of similar rock have previously been observed cutting the higher members of the complex at several places, but nowhere the Paleozoic rocks.

Granite

Granite underlies the central part of the Beartooth Range, and from the Stillwater Canyon eastward it extends upward approximately to the base of the Stillwater complex. It cuts a mixed zone of norite and hornfels on the east side of the Stillwater Canyon and may have cut out a part of the complex in the valley itself. It is a coarse-grained, gray to pink biotite granite with an indistinct gneissoid structure believed to be primary. It is pre-Cambrian in age but apparently belongs to a distinctly later period of intrusion than the Stillwater complex.

PALEOZOIC ROCKS

At the mountain front upturned Paleozoic rocks have been carved by erosion into a series of palisades. To the south several areas of limestone have been preserved in downfaulted blocks. (See pl. 63.) The lowest Paleozoic formation everywhere contains boulders of norite and gabbro from the Stillwater complex.

The writers made no study of the Paleozoic rocks in this area, and the boundaries shown on plate 63 are taken from an unpublished map by J. S. Vhay.

SURFICIAL DEPOSITS

In most of the valleys of the region glacial drift and alluvial cones mask the bedrocks, but on the divides surficial material is lacking or consists only of a thin residual mantle. The Stillwater complex is completely covered by glacial debris for about 2 miles from the east end of the Benbow claims to a point just beyond the West Fork of Fishtail Creek. A long moraine is piled up between the parallel valleys of branches of Little Rocky and Fishtail Creeks. Some glacial drift covers the east side of the valley of Little Rocky Creek above the Benbow camp.

The valley of Nye Creek, which is known as Nye Basin, is filled with glacial debris apparently somewhat disturbed by landslides. The Stillwater River Valley is covered with alluvial material, and glacial drift clings to the walls of the canyon at the mouths of hanging valleys such as those of Nye and Woodbine Creeks.

STRUCTURE

The structural features of the Stillwater complex may be divided into two categories, primary and secondary. Although it is not possible at some places to decide whether a structure is primary or secondary, it is desirable to do so where possible because of certain economic implications.

Primary structure

One of the most remarkable features of the Stillwater complex is the arrangement of the various rock types in layers. It is believed[15] that these layers were virtually horizontal

15/ Peoples, J. W., Gravity stratification as a criterion in the interpretation of the structure of the Stillwater complex, Montana: 16th Internat. Geol. Cong. [1933] Rept., vol. 1, pp. 353-360, 1936.

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when they were formed and that they have since been tilted and faulted into their present attitudes. Layering is best illustrated in the upper zones of the complex, which are made up of elongate lenses that contain the same minerals but in widely differing proportions and range in thickness from an inch or less to hundreds of feet.

In the ultramafic zone banding is less conspicuous than in the higher zones, but there is a broad parallel arrangement of the rock types. The upper part of this zone everywhere consists of bronzitite. Near the middle of the zone harzburgite, partly serpentinized, is everywhere present. Chromite bands occur in this harzburgite, never above it. Below the middle layer of harzburgite, which at the eastern end of the complex is about 1,000 feet thick, both bronzitite and harzburgite are found.

Banding on a smaller scale has been observed in some places. Alternate layers of chromite and harzburgite are especially conspicuous in the cliff above Mountain View Lake, on the west side of Stillwater Canyon. The chromite layers range in thickness from about a quarter of an inch to about 2 feet, and at one place 17 of them were counted in 52 feet of section. The chromite layers are not continuous; some of them merge into others and some are lenticular.

The primary banding of the ultramafic zone is obscured in many places by dunite or olivine-rich harzburgite that has been intruded into bronzitite and banded harzburgite. The intrusive relation was first noticed by the writers in 1931 near the west end of the complex, where it has since been studied by Sampson and by Hess,[16/] who has discussed its origin. The intrusive rock and the earlier harzburgite are so similar that in many

16/ Hess, H. H., A primary peridotite magma: Am. Jour. Sci., vol. 35, pp. 334-340, 1938.

exposures it is impossible to distinguish them. On the detailed map of the Benbow claims two textural varieties of harzburgite, poikilitic and granular, are distinguished. Some of the poikilitic harzburgite is intrusive into the granular harzburgite.

Secondary structure

Tilt of banding

The present attitude of the rock layers of the Stillwater complex resulted from deformation, which took place long after the rocks consolidated. For most of the length of the complex the layers now strike between N. 60° W. and N. 80° W., but at two places in the ultramafic zone the strike deviates widely from this and is far from parallel to the contact with the banded zone above. One of these places is in the cliff above Mountain View Lake, where the chromite layers strike N. 10° E. and dip 50°-60° W. On Iron Mountain, 8 or 9 miles west of the Stillwater River, is a similar divergence from the normal strike. No satisfactory explanation of these discrepancies can be made at this time. Near the west end of the complex the dip ranges from 30° to 60° N., but at the east end the dip is almost vertical and the chromite layers dip to the north in some places and to the south in others.

Faults

Plate 63 shows several reverse faults of easterly trend near the mountain front. The possibility that similar faults have duplicated parts of the ultramafic zone in the eastern part of the complex was considered, as the thickest section of this zone is on the Nye Basin-Little Rocky Creek divide, but no evidence was found for such faulting.

The chromite is offset at many places on the Benbow claims, and at nearly every place the offset is to the right. Many of these offsets are due to faults striking N. 20° W. to N. 20° E. and dipping from about 50° E. to 50° W. The total displacement could not be determined on any of these faults, but the horizontal offset is commonly 15 to 50 feet and on some is as much as 200 feet. In the Eclipse adit, in addition to two faults of the above type, many low-angled faults of small displacement were observed, and in the Black Rock adit a horizontal fault cuts off the ore. Detailed study revealed more faults than were expected, and mining probably would reveal a great many more.

Cumulative evidence has shown that some of the offsets are due to the thinning out of one chromite band opposite the beginning of another that is at a slightly higher or lower horizon. As these offsets are to the right like those due to faulting, it is impossible at many places, for lack of exposures, to determine whether the offset is due to thinning out or faulting.

Geologic history

It is believed that the Stillwater complex solidified, at an unknown depth, as a great saucer-shaped mass of layered igneous rock, over 16,000 feet thick [17/] and at least 30 miles in diameter, which rested on a horizontal series of sedimentary rocks. Before Middle Cambrian time the roof and parts of the complex itself were eroded, the greatest erosion of the complex being, of course, at the edge of the saucer. The seas of Middle Cambrian time then covered the area and deposited limestone and shale over the complex. Near the center of the saucer the

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17/ Peoples, J. W., Gravity stratification as a criterion in the interpretation of the structure of the Stillwater complex, Montana: 16th Internat. Geol. Cong. [1933] Rept., vol., 1, pp. 353-360, 1936.

limestone beds were parallel to the banding of the complex, but at the edge the horizontal sediments rested on the gently dipping truncated layers of igneous rock. Deposition took place intermittently throughout Paleozoic and Mesozoic time.

With the uplifting of the Rocky Mountains during the Laramide Revolution the Beartooth Mountains were arched into an anticline. On the north side the Paleozoic beds and the underlying saucer of igneous rocks were turned on edge and then were thrust out over the plains along the Beartooth thrust faults. Other faults, probably of the same age, broke the complex and displaced the bands.

Erosion planed off the mountains, which were later re-elevated. Sharp V-shaped valleys were carved by northward-flowing streams. In Pleistocene time ice filled the valleys, deepened them, and abraded their walls. The great ridge of bouldery debris piled up between the East Fork of Little Rocky Creek and the West Fork of Fishtail Creek was deposited by a glacier overflowing both these valleys. Since the period of glaciation erosion has removed some of the glacial debris, and tributaries have deposited alluvial fans in the Stillwater Valley.

ORE BODIES

General statement

The term "ore" is applied in this report to material that, although it cannot now be profitably mined, might yield a profit if prices rose and metallurgical practice was improved. Perhaps "potential ore" is a more accurate term. All gradations from nearly pure chromite to barren rock are found, but no deposits containing less than 15 percent of chromite were considered as potential ore.

Although the chromite deposits show many variations, they all form steeply-dipping layers and lenses parallel to the general layering of the complex; and all occur in poikilitic harzburgite--none in bronzitite.

Chromite has been found at intervals for 27 miles along the same general horizon in the complex, but instead of being one continuous body it forms a series of overlapping lenses, as anorthosite does in a higher zone. An almost constant associate of the chromite is a very coarse grained or pegmatitic harzburgite with interstitial feldspar and disseminated chromite grains. This rock may occur above, below, or within the chromite-bearing layer. (See figs. 51-53.)

The richest streaks of ore, which contain about 85 percent of chromite by volume, grade into very lean material. In the thick layer of chromite ore in the eastern part of the War Eagle claim the rich streaks are at or near the top, i. e., to the north. The thinner chromite-bearing layers commonly contain a rich streak on the footwall, with a few inches to a few feet of rock containing disseminated chromite above it. There are almost continuous gradations in places from nearly pure chromite to rock with scattered chromite crystals. On the west side of Stillwater Valley a series of chromite bands from a quarter of an inch to about 2 feet in thickness alternate with bands of fresh harzburgite and basic pegmatite. The harzburgite itself contains accessory chromite.

Mineralogy

The mineralogy of the chromite bands is simple and is similar to that of the complex as a whole, except in the proportion of minerals. In the complex the only primary minerals are plagioclase, orthopyroxene, clinopyroxene, olivine, and chromite; serpentine is the most common secondary mineral. The same minerals occur along the chromite horizon, which is distinguished merely by the concentration of chromite.

The only ore mineral is referred to as chromite, but it departs widely from the theoretical composition $FeCr_2O_4$ or 68 percent of Cr_2O_3 and 32 percent of FeO. A chemical analysis, reported by the Bureau of Mines,18/ of a cleaned sample of chromite from the Benbow property is as follows:

FeO	24.05
Cr_2O_3	46.09
Al_2O_3	23.81
MgO	5.43
SiO_2	1.02
	100.40

The formula for this chromite should be written $(Fe,Mg)O\cdot(Cr,Fe,Al)_2O_3$, and the composition falls within the range of what Fisher 19/ calls chromo-hercynite, which is characterized by abundant Al_2O_3. The pure mineral thus contains only about two-thirds as much chromium as $FeCr_2O_4$, and no mechanical means of concentration, of course, can raise the grade of the ore above 46 percent.

Even the highest-grade ore contains some silicate material. The commonest silicate in the ore from the Benbow claims is serpentine derived from the alteration of olivine and bronzite. These minerals are not completely altered in all of the ore; fresh enstatite and olivine are associated with the chromite on the west side of the Stillwater Canyon. Plagioclase is rarely present in the good ore, but in rock containing low concentrations of chromite it is common, and most of the chromite grains are enclosed in it. In the basic pegmatites associated

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18/ Koster, J., Studies on the treatment of domestic chrome ores: U. S. Bur. Mines Report of Investigation 3322, p. 7, 1936.

19/ Fisher, L. W., Chromite, its mineral and chemical compositions: Am. Mineralogist, vol. 14, p. 344, 1929.

with the ore, chromite commonly shows preference for the diopside and plagioclase.

On the hill east of the Benbow camp the country rock and the ore are both traversed by veinlets of light-colored serpentine, which in general are parallel to the strike and dip of the chromite layers. In these serpentine veins, chromite octahedra as much as 6 millimeters in diameter have been seen. In the normal ore the grain size is much smaller, ranging from 0.1 to 1.5 millimeters.

Origin

The chromite of the Stillwater complex is of magmatic origin. Chromite is one of the essential primary minerals of the complex, the others being orthopyroxenes, diopside, olivine, and plagioclase. Each of these minerals, except diopside, is concentrated in many sheetlike masses of almost monomineralic rock, although, of course, each rock grades into others. In the upper part of the complex are layers and lenses of anorthosite, or plagioclase rock; in the ultramafic zone are layers and lenses of pyroxenite (bronzite rock), dunite (olivine rock), and chromite rock--or ore.

Westgate [20] expressed a similar view. He says, "It is clear that the origin of the chromite and that of the peridotite facies of the pyroxenite are parts of the same problem." Schafer [21] suggested that the sharply defined footwall and upward dissemination indicate crystal settling of the chromite. A detailed study of the origin of the Stillwater chromite by Sampson has shown many interesting features. This work is still unpublished, but Sampson has indicated orally that the

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20/ Westgate, L. G., Deposits of chromite in Stillwater and Sweet Grass Counties, Mont.: U. S. Geol. Survey Bull. 725, pp. 67-84, 1921.

21/ Schafer, P. A., Chromite deposits of Montana: Montana Bur. Mines and Geology Mem. 18, v. 35 pp., 1937.

deposits are very similar to those of the Bushveld complex, which he has interpreted as magmatic deposits.[22/]

If, as the writers believe, the chromite deposits were formed essentially at the same time as the enclosing rocks, it seems reasonable to assume that they extend to as great depth as the ultramafic zone of the complex. The depth to which mining may go if undertaken is likely therefore to be determined by economic factors.

Localization of ore bodies

The chromite-rich layers are all in the ultramafic zone of the complex and, east of the Stillwater River at least, mainly near the middle of that zone. Above Mountain View Lake the chromite bands seem to be above the middle of that zone, but here abnormal dips and strikes and lack of exposure in a critical interval combine to obscure the relations. The chromite lenses all occur in harzburgite or its serpentinized equivalent, and the chromite is mainly associated with the poikilitic harzburgite. Some of the thin 1/2- to 1-inch seams are at contacts of poikilitic harzburgite with either granular harzburgite or bronzitite.

Continuity and size of ore bodies

Although chromite concentrations can be found in the middle part of the ultramafic zone along most of the length of the complex, there is no single chromite-rich band continuous throughout.

The detailed map of the Benbow claims shows many offsets, most of them to the right, in the main chromite band. Many of these offsets are due to displacement along northward-striking

22/ Sampson, Edward, Magmatic chromite deposits in southern Africa: Econ. Geology, vol. 27, pp. 113-144, 1932.

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faults, but many others are due to the overlapping of chromite lenses that are at slightly different horizons in the ultramafic zone.

About 150 feet west of the Black Rock adit one lens of chromite pinches out within a distance of 6 feet and an overlapping lens occurs 200 feet to the north. An irregular zone of overlapping chromite lenses, with disseminated chromite between, occurs in the eastern part of the War Eagle claim. (See pl. 64.)

The chromite deposits differ in character along the strike. Near the east end of the Benbow claims chromite occurs over a thickness of 15 to 50 feet as layers and irregular lenses in chromite-bearing harzburgite. At some places on these claims the chromite is concentrated in a single layer 7 inches to 5 feet thick with sharp walls, but more commonly layers of chromite-rich and chromite-poor rock alternate over a width of 2 to 25 feet. Commonly on the hanging wall and in some places on the footwall the contact is gradational. On the west side of the Stillwater River chromite is distributed through a much greater thickness of ultramafic rocks and is concentrated in at least three zones, the lowest of which contains chromite in irregular streaks and pods and as disseminated grains in harzburgite through a variable thickness. The two upper zones, which are about 200 feet apart, contain comparatively regular alternating layers of nearly solid chromite and chromite-rich harzburgite through a thickness ranging from a few feet to more than 50 feet.

Although it is believed that there was never a continuous chromite layer, any columnar section of the complex would probably show at least one layer of chromite. Chromite is apparently absent in some places because of faulting, but as the faults are almost perpendicular to the strike of the banding the barren stretches due to this cause are not long.

The chromite band on the Majestic claim shows many small offsets, even though ore was found in nearly all the trenches dug at 50-foot intervals. These offsets are thought to be due to faults, though few of the faults could be located.

Plate 64 indicates the proved horizontal extent of the chromite bodies on the Benbow properties. The thickness, length, area of surface, and altitude are summarized in table 2. The variation in altitude in this area is 900 feet, and in the complex as a whole the writers have seen the chromite at all altitudes from 5,500 to 10,000 feet. It is to be expected therefore that the chromite in the Benbow district will continue to depths of several hundred or even several thousand feet, with only such variations in thickness and grade as appear at the surface.

Table 2.--Dimensions, in feet, of chromite deposits on the Benbow claims

Claim	Length of out-crop	Average horizontal width	Area of surface (sq.ft.)	Average height above Eclipse adit 1/
Big Seven	500	6.3	3,150	405
Majestic	1,446	7.0	10,120	761
Titanic	882	4.8	4,230	643
Black Rock	446	3.6	1,605	294
Eclipse	510	5.2	2,660	185
Lucky Strike	1,080	5.1	5,500	353
War Eagle	365	5.8	2,120	354
Total (without disseminated ore).	5,229		29,385	
War Eagle (disseminated ore)	430	29.5	12,090	311
Total (with disseminated ore).	5,659		41,475	
Weighted average (without disseminated ore).		5.7		498

1/ Altitude of Eclipse adit 8,210 feet.

Reserves

Basic considerations

An estimate of ore tonnage depends upon assumptions regarding the thichness, continuity, depth, specific gravity, and grade of the ore. Sufficient information on these factors for a reliable estimate is available only on the Benbow property.

The thickness, length, surface area, and average altitude of the chromite bodies on this property are summarized in table 2.

The fact that chromite has been found in the Stillwater complex at all altitudes from 5,500 to 10,000 feet without any systematic change ascribable to difference in depth indicates that it probably would continue to any minable depth. The changes in thickness and grade at the surface over a range in altitude of 900 feet on the Benbow property should be a measure of the variation to be expected with depth.

In order to determine the specific gravity of the chromite a specimen of ore from Pit A-1 with a specific gravity of 3.69 was crushed to pass 45 mesh, and two fractions were separated by tetrabromethane. The heavy fraction constituted 76 percent of the sample, the light fraction 24 percent, by weight. The heavy fraction, which contained a few compound grains, was recrushed to pass 65 mesh and was put through the heavy liquid twice. This material, which was presumably rather pure chromite, had a specific gravity of 4.39 as determined with a pycnometer. Curves were drawn to connect the specific gravity of the ore with weight and volume percentage of chromite, and where assays were available the specific gravity could be calculated from these curves. Where assays were lacking, visual estimates, made in the field, of volume percentages of chromite were used. The silicate material in the ore on the Benbow property was assumed to be all serpentine, with specific gravity about 2.5, but if the ore contains any of the original silicates, which all have higher specific gravities, the weight per cubic foot assumed is too low, and the estimated tonnage is correspondingly low. West of the Stillwater River the silicates associated with the chromite are fresh olivine and bronzite, each of which has a specific gravity of about 3.3. A cubic foot of ore of a given grade from this locality will accordingly be heavier than a cubic foot of ore of the same grade from the Benbow property.

There are all gradations from massive chromite with only a few percent of silicate material to silicate rocks with merely accessory chromite. In order to make a satisfactory estimate of reserves, it would be necessary to decide what minimum proportion of chromite would be required to constitute potential ore. This in turn would depend on the price of chromite, and on the costs of mining, milling, and transportation. None of these factors can be closely estimated for the future. In the Stillwater complex there is no known occurrence of high-grade chromite ore nor any that could probably be milled to what would be classed by present standards as a high-grade concentrate. All the ore contains less than 40 percent of Cr_2O_3, for, as has been shown, even the pure chromite crystals contain no more than 46 percent of Cr_2O_3, and none of the ore is free from silicates. All the ore will probably have to be concentrated.

Two types of chromite-bearing material were considered. The main band throughout a length of more than 5,200 feet ranges between 30 and 80 percent, by volume, of chromite and probably averages between 40 and 45 percent. Near the east end of the property there is no single band of ore, but the country rock contains streaks and disseminated grains of chromite. This chromite-bearing rock, which is referred to as "disseminated ore," has been mapped for a length of 430 feet; its average width is 29.5 feet. Its chromite content is probably close to 15 percent by volume; but even though it is of such low grade, this block contains more chromite per linear foot of outcrop than any other section of equal length on the property.

Tests made on ore from the Benbow property indicate that the richest concentrate that could be made would contain 45 percent of Cr_2O_3.[23/]

Reserves on the Benbow property

The tonnage of ore per foot of depth for each of the claims on the Benbow property is given in table 3, and the possible tonnage above the Eclipse adit level is given in table 4. These estimates are based upon the 5,660-foot length of the chromite band that has been demonstrated by trenching and on estimates of the weight per cubic foot of ore. The distance along the strike between the easternmost proved exposure on the War Eagle claim and the westernmost exposure on the Big Seven claim is about 9,000 feet. This distance includes intervals without exposure, totalling about 3,300 feet, in which no chromite has yet been found. Although in estimating reserves it was assumed that these intervals are barren of chromite, there may be chromite beneath the wash for most of this distance, perhaps for 2,000 feet.

The following formula was used for estimating tons of ore per foot of depth:

$$\frac{\text{Sq. ft. of surface x pounds of ore per cu. ft.}}{2{,}000} = \text{tons}$$

23/ Doerner, H. A., Concentration of chromite: U. S. Bur. Mines Report of Investigation 3044, p. 3, 1930.

From the tons per foot of depth and the average thickness of the chromite ore above the Eclipse adit level the estimates of the possible tons of ore above that level were calculated. The disseminated ore on the War Eagle claim was considered separately. This grand total implies that, if ore may be considered as "proved" to an average depth of 50 feet, approximately 200,000 short tons of ore is available. The indicated "possible" ore above the Eclipse adit amounts to 1,820,000 short tons. Table 4 shows a comparison of this estimate with estimates made previously by others.

Table 3.--Chromite ore, in short tons, per foot of depth indicated by trenching on the Benbow claims

Big Seven	331	War Eagle (compact ore)	197
Majestic	1,066	Total (without disseminated ore).	2,963
Titanic	457		
Black Rock	171	War Eagle (disseminated ore).	1,112
Eclipse	171		
Lucky Strike	570	Grand total	4,075

Table 4.--Chromite ore above the Eclipse adit

Estimated by	Thickness (feet)	Cr_2O_3 (percent)	Ore (short tons)
Peoples and Howland, 1940	5.7	25.6	1,475,000 [1]
	29.5	11.8	345,000 [2]
			1,820,000
Roesler [3]	3.5	27.0	900,000
Kemp [3]	4.65	27.37	1,090,000
Schafer [3]	4.0	29.82	1,200,000
McClain, 1936 [4]	5.0	27.30	2,004,000

1/ Compact ore.
2/ Disseminated ore.
3/ Schafer, P. A., Chromite deposits of Montana: Montana Bur. Mines and Geology Mem. 18, p. 19, 1937.
4/ Private report for Chromium Products Corporation.

DESCRIPTION OF DEPOSITS

Benbow claims of the Chromium Products Corporation

The so-called Benbow claims of the Chromium Products Corporation comprise seven patented claims, which lie in secs. 28, 29, and 30, T. 5 S., R. 16 E. They begin west of the Stillwater-Little Rocky divide and extend across the valley of Little Rocky Creek for a total length of about 2 miles. The mining camp, which is on Little Rocky Creek, includes 3 cabins, a compressor house, and a stable. It is reached by a wagon road from Dean, 9 miles distant. This road is narrow and steep, and until work was done on it by the Bureau of Mines in 1939 it was barely passable for a team and wagon.

The property is developed by four adits, one of which includes 860 feet of work, and several trenches, most of which were filled with debris in 1939. New trenches dug by the Bureau of Mines party exposed the chromite at 50-foot intervals for a distance of nearly 6,000 feet along the strike.[24] Plate 64 shows the chromite bodies on the property. The character of the ore is illustrated by sketches of several of the pits (figs. 51-54, 56-64).

War Eagle claim.--The easternmost known outcrop of chromite is on the War Eagle claim. East of this outcrop the ground slopes downward to a wide moraine-filled valley, which contains the East Fork of Little Rocky Creek and West and East Forks of Fishtail Creek. Pits along the strike in this direction do not expose any chromite. At its easternmost exposure the chromite ore is of medium grade and is 1.5 feet thick. Westward the chromite band expands to a width of 20 to 50 feet for a distance of about 300 feet. The bedrock in this section crops out

24/ Jackson, C. F., In quest of strategic mineral supplies in the field: Eng. and Min. Jour., vol. 140, No. 12, pp. 43-46, 1939.

in many places and is within a few inches of the surface in other places. The chromite-bearing rock is of low grade and consists of streaks of disseminated chromite in barren serpentinized harzburgite, usually with one or two rich bands from 1 to 2 feet wide.

Figure 54 is a sketch of an outcrop near the middle of the chromite zone between pits A-46 and A-47. Noteworthy in this exposure is the northerly strike of some of the chromite

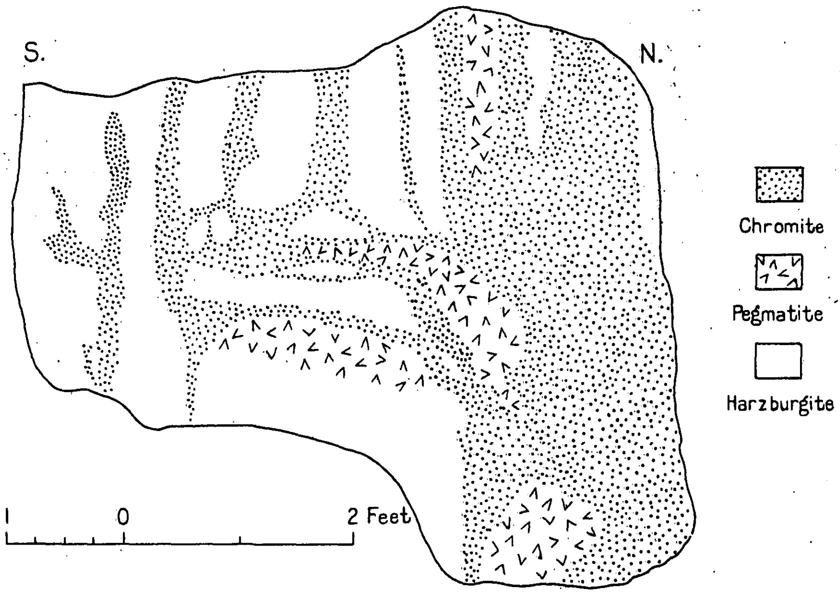


Figure 54.--Sketch plan of horizontal surface between pits A-46 and A-47, War Eagle claim. Shows streaks of disseminated chromite near middle of 30-foot ore zone.

streaks, which connect streaks that have the normal easterly trend. The uneven width of this disseminated zone, its low grade, its rapid narrowing at both ends, and the cross-trending streaks suggest that some of the irregularities are due to original irregular segregation of the chromite. However, two sharp offsets in this section are mapped as faults. This wide zone of disseminated ore is estimated to contain more chromite per unit length than the narrower parts of the zones to the east and west of it, even though these parts contain more chromite per unit volume.

West of the wide part of the zone the chromite averages 3.8 feet in width, but it pinches out near the west end of the claim.

Lucky Strike claim.--The easternmost exposure on the Lucky Strike claim is about 150 feet from the nearest exposure on the War Eagle, and chromite is thought to be absent in this interval. The chromite has been proved to be continuous for a length of about 1,100 feet on the Lucky Strike claim. A gap of 400 feet on the western part of the claim is the longest in which no chromite has been found; but as this strip is covered with wash and contains no outcrops it is uncertain whether the gap is due to tapering out or to faulting of the ore. Two small faults offset the chromite at the west end of the claim, and faulting may also account for the offsets toward the eastern end.

The chromite-bearing layer ranges in thickness from 1 to 11 feet and averages over 5 feet. Throughout most of the length of the claim the chromite is concentrated in one or two bands which are bordered by minor quantities of disseminated chromite. The disseminated chromite is most commonly on the upper side of the band (see fig. 53), but in some places it is on the lower side or forms a parting between two richer bands. The potential ore on the claim is estimated to contain about 60 percent of chromite by weight.

A streak 1 to 2 inches wide occurs 380 feet south of the main layer near the west end of the claim, and nodular masses of chromite an inch or so across occur in pegmatitic harzburgite 24 feet south of the main layer near the center of the claim.

Eclipse claim.--The chromite on the eastern end of the Eclipse claim lies about 250 feet north of the layer at the west end of the Lucky Strike, and it may be in a different lens, for it contains only half a foot of massive chromite and 5 feet of disseminated chromite, the disseminated chromite being north of the massive streak. The ore maintains this general character to a point about 200 feet from the eastern-end line, where it is again interrupted by a gap of 150 feet in which no chromite has been found.

The only part of the property for which there is any extensive subsurface information is on the slope east of Little Rocky Creek, and an attempt is made to show the relations there in three dimensions by an isometric block diagram. (See pl. 65.) A map of the Eclipse adit is shown in figure 55.

Two faults of considerable displacement cut the chromite in the adit. The strike of the western fault can be determined within narrow limits from its position in the two parallel drifts. The strike of the eastern fault is inferred from cave-ins at the eastern ends of the two shorter drifts. These faults are assumed to account for the offsets of the chromite at the surface east of pits B-11 and B-7. The nearly vertical eastern raise is in chromite for a height of 90 feet. The western raise is lagged all the way to the surface, thus concealing any chromite that it might cut. If the outcrop at the surface connects with the exposure in the adit the chromite layer must have a southerly dip of 65°-70°. As the chromite layer is vertical or dips steeply to the north wherever it has been seen, alternative explanations for the apparent southerly dip are suggested.

An older eastward-striking fault may lie between the two northward-striking faults. Such a fault has been tentatively drawn in on the block diagram. No such fault apparently inter-

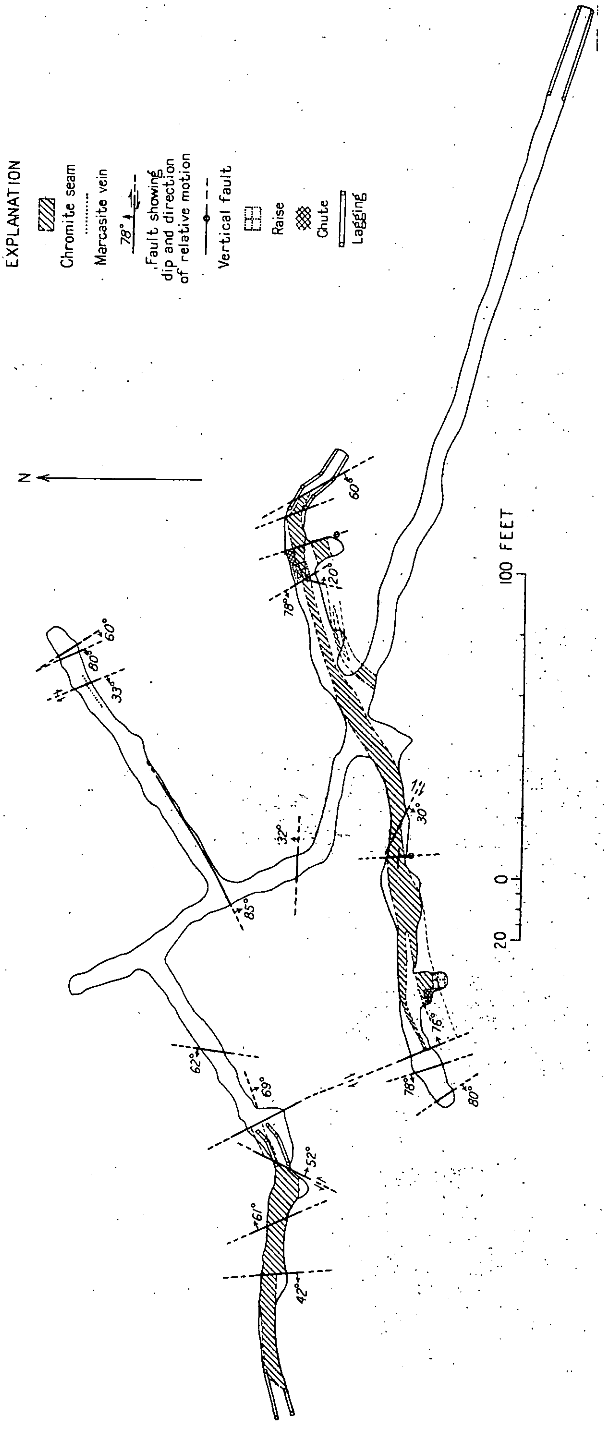


Figure 55.--Map of Eclipse adit. From tape and compass survey by A. L. Howland and J. W. Peoples.

sects the adit, and the supposed fault is, therefore, assumed to have a dip of at least 60° N., which would carry it north of the adit. If the small fault with an offset to the left, seen a few feet above the portal of the adit, is nearly horizontal, it would separate the chromite band at the surface from the band in the section of the adit near the portal.

The alternative explanation is that the layers of chromite in the adit and at the surface may represent different lenses, although the apparent connection of the two at the portal is against such an interpretation.

Several faults with displacements ranging from a few inches to a few feet can be seen in the adit. These small dislocations are, no doubt, very common throughout the whole length of the chromite-bearing zone, but they are visible only where exposures are good.

Exposures are poor on the west side of Little Rocky Creek, but the known occurrences of the chromite indicate a fault with an offset of about 150 feet in the valley of Little Rocky Creek and perhaps others on the slope east of the Black Rock adit.

A seam of chromite a few inches wide was observed at two places 700 to 800 feet south of the west end of the Eclipse claim and a few hundred feet east of the trail that leads from Little Rocky Creek to Nye Basin.

Black Rock claim.--The Black Rock adit is on a chromite lens about 200 feet in length and 4 feet in average width. Several small faults of only a few feet displacement cut this lens. The adit, which is 30 feet long, extends northwestward along the seam for about 20 feet, then curves to the north for 10 feet more to follow the chromite, which is offset 4 feet to the right a few feet from the portal. Slickensided surfaces on the wall of the adit near the portal suggest some movement along the south side of the chromite layer.

About 200 feet north of this lens is another, which is from 2 to 3 feet wide and 100 feet long. The exposures in the next 750 feet to the west are very poor, particularly in the small stream valley. No chromite was found, though serpentinized harzburgite crops out by the stream near an old pit. It seems likely that more extensive prospecting would locate chromite in this interval, but long and deep trenches might be necessary.

Beyond this gap the chromite extends 110 feet to the upper end of the discovery pit of the Titanic claim, where it apparently is offset to the north by a fault.

Titanic claim.--A chromite layer averaging nearly 4 feet in thickness is considered proved on the Titanic claim for a linear distance of about 900 feet along the strike. Another streak

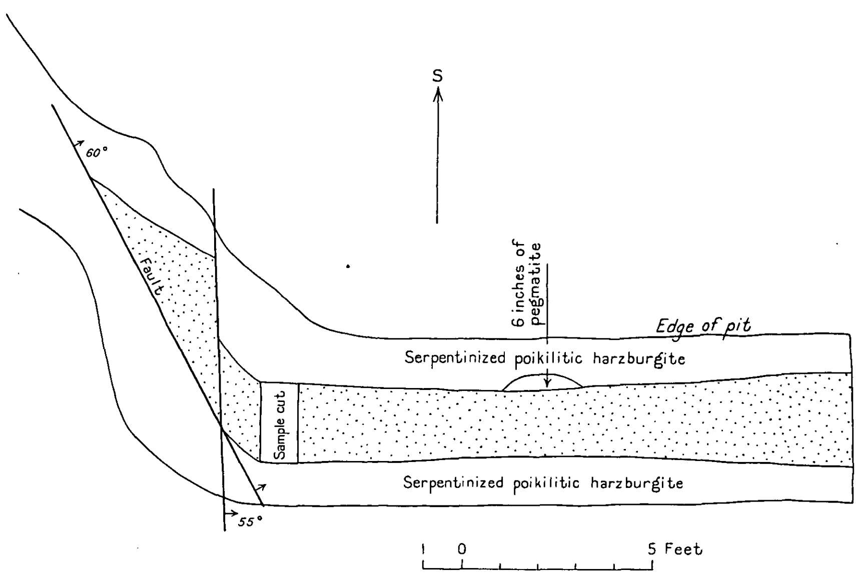


Figure 56.--Plan of pit C-15, Titanic claim.

of chromite less than an inch thick parallels the main layer about 100 feet north of it.

In the discovery pit, at the east end of the claim, chromite-rich layers alternate with serpentinized harzburgite that contains disseminated chromite. The total width of the chromite-bearing zone is 5 to 6 feet for a length of about 20 feet. Slickensided fractures and veins of light-colored serpentine make a complex pattern in the face of the pit. Just west of the pit the chromite is apparently shifted 200 feet to the north by a fault, but if so it is only 1 foot thick on the west side of the fault.

West of the fault is a gap of 350 feet in which no chromite has been found. The ore may be covered by relatively thick wash, but the exposure at each end of the gap (fig. 56) indicates that if present it is thinner than normally.

From the Forest Service trail to the west end of the claim, chromite is exposed in all the trenches, which were dug at 50-foot intervals. Its thickness ranges from 2 to 10 feet but is between 3 and 5 feet in most exposures. Its dip is steep, ranging from 80° N. to 80° S.

Majestic claim.--The Majestic claim, which bestrides the Little Rocky Creek-Stillwater divide, has an average altitude of nearly 9,000 feet, the greatest of any claim in this group. The highest outcrop of chromite is at 9,110 feet.

In calculating tonnage the authors assumed that the chromite was proved for about 1,450 feet along the strike. Ore was found throughout this distance in all the trenches, which were dug at 50-foot intervals except in a short stretch in the gulch just west of the Majestic adit, where the mantle is not only thick but contains boulders so large as to make trenching impracticable. Some of the many offsets in the course of the chromite layer are due to north-trending faults that have been located; others are thought to be due also to faults, for no evidence was seen of overlapping chromite lenses.

The ore is offset in the Majestic adit, located on the west side of the Little Rocky Creek-Stillwater divide at an altitude of 8,990 feet. This adit in several places is almost filled

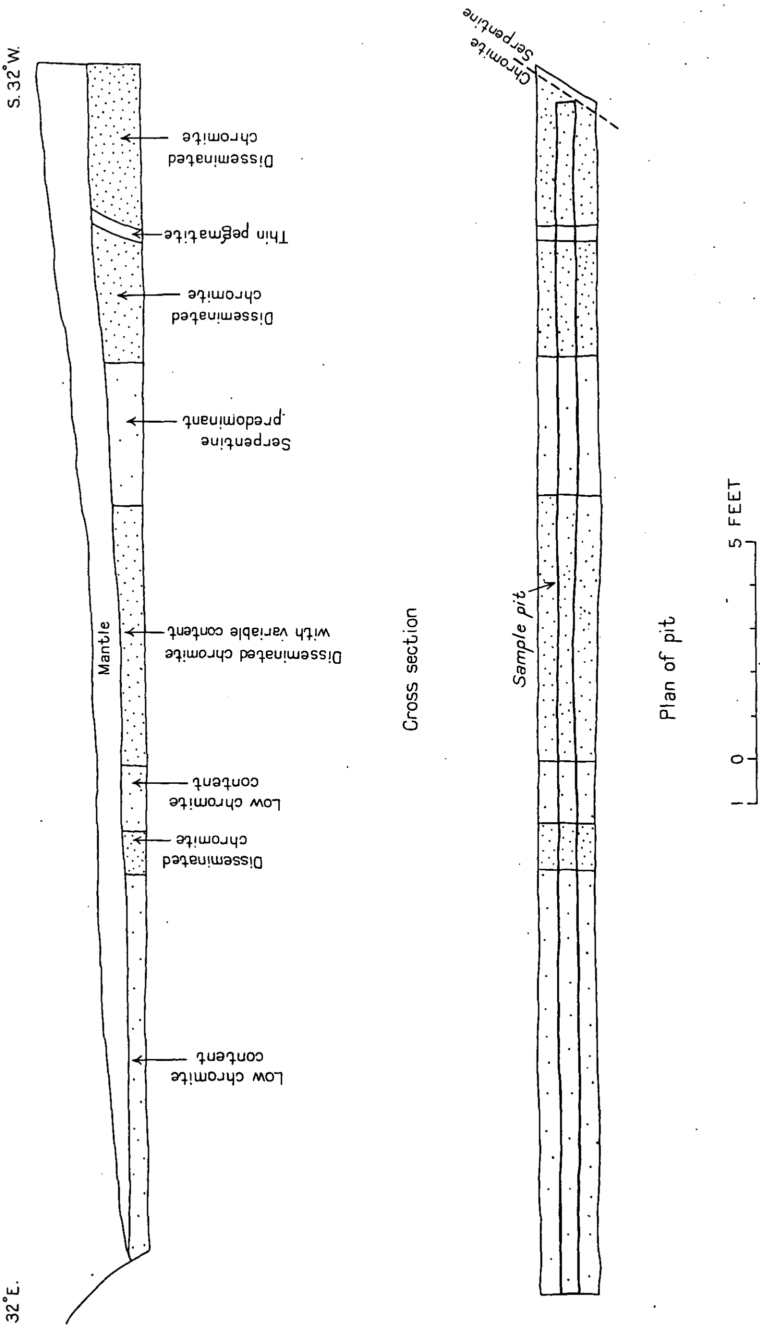
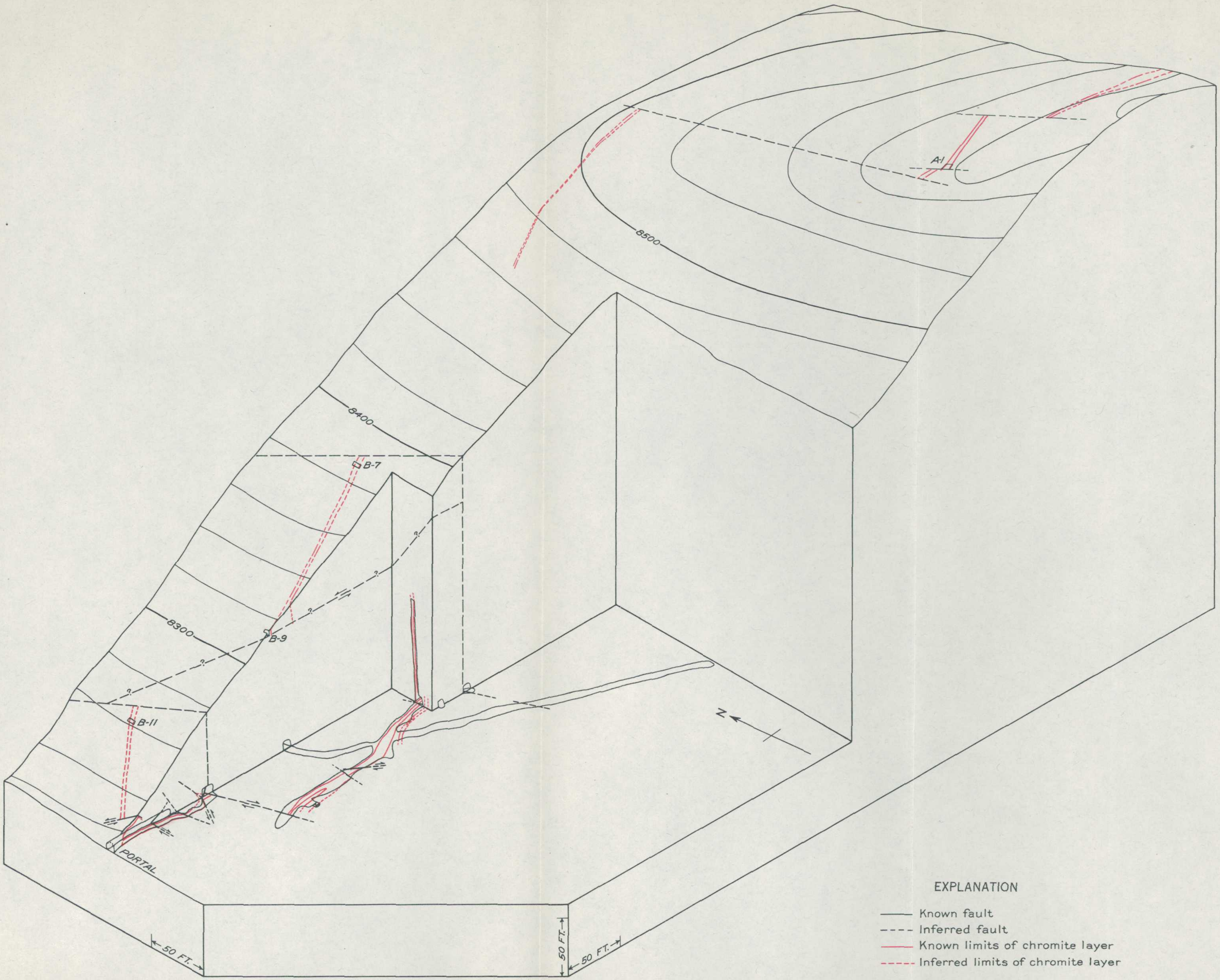


Figure 57.--Plan and cross section of pit C-39, Majestic claim.



ISOMETRIC BLOCK DIAGRAM OF ECLIPSE ADIT AND SURFACE EXPOSURES ON PARTS OF ECLIPSE AND LUCKY STRIKE CLAIMS with slump from the walls; part of it is lagged, so gives little opportunity for study of the chromite. The ore, however, evidently was followed to a point about 65 feet from the portal, where it is offset to the south. The tunnel bends southeastward here and re-enters the ore at the breast, 180 feet from the portal.

The chromite layer varies in character and thickness from place to place. For example, the chromite is disseminated over a width of 20 feet in two pits near the divide, C-39 and D-1 (see figs. 57 and 58), although both to the east and the west

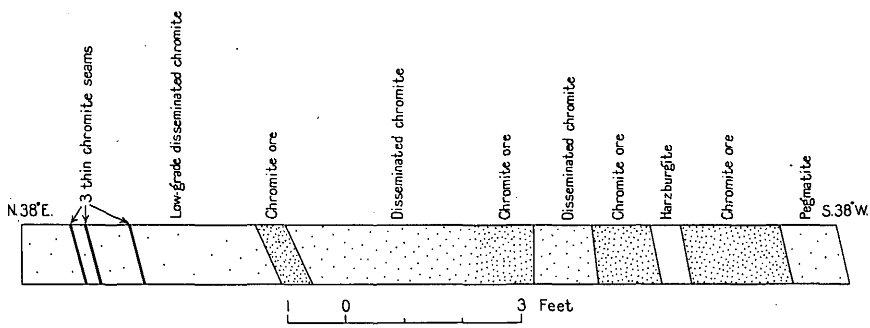


Figure 58.--Plan of pit D-1, Majestic claim.

it is concentrated in a thinner but richer streak. (See fig. 59.) It is estimated that the chromite-bearing material on the claim averages 7 feet in thickness and about 50 percent of chromite by volume. The character of the ore is shown in figures 57-62. Some of the offsets in the chromite layer on this claim are certainly due to northward-striking faults, and all are thought to be due to faulting.

North of the layer and near the divide three chromite seams half an inch to 2 inches thick have been mapped. None of these could be traced for much more than 100 feet because of poor exposures, but wherever observed they are regular. A similar seam lying south of the main layer and extending along a contact between bronzitite and harzburgite was seen near the trail to the plateau. Another seam, a few hundred feet from the base of the complex, was found on the divide outside the limits of the area mapped in detail. None of these thin seams

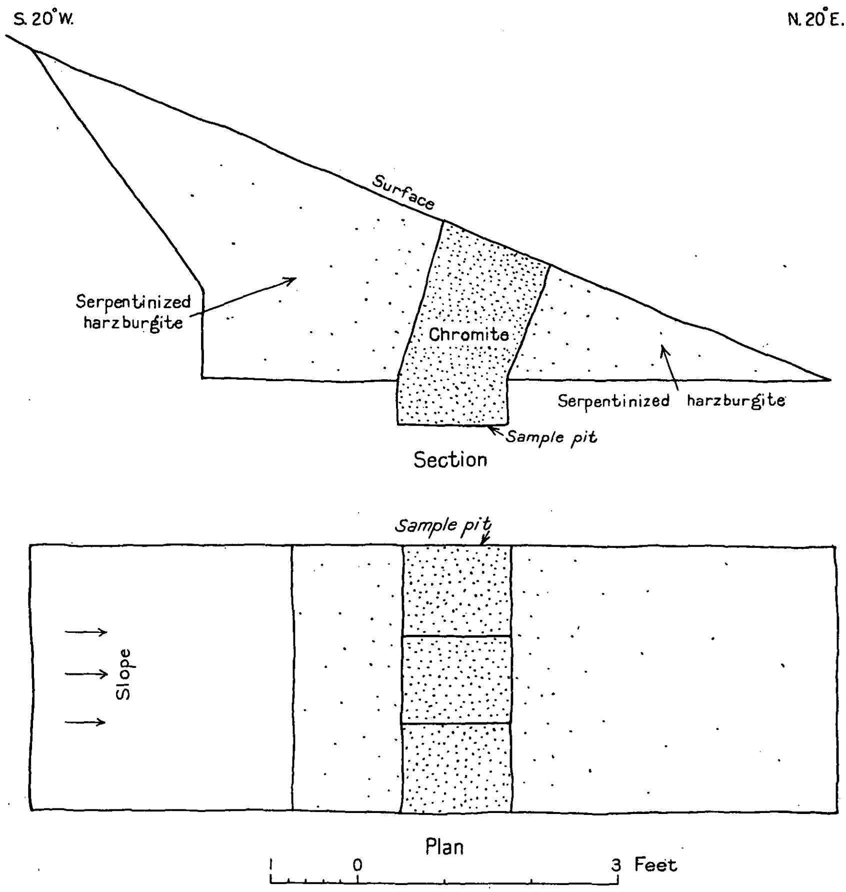


Figure 59.--Plan and cross section of pit D-3, Majestic claim.

could be profitably mined, but if they are at all persistent they may be useful as guides to the main layer where it is covered.

Exposures are better on the Majestic claim than on the Titanic and much of the Black Rock; they are particularly good

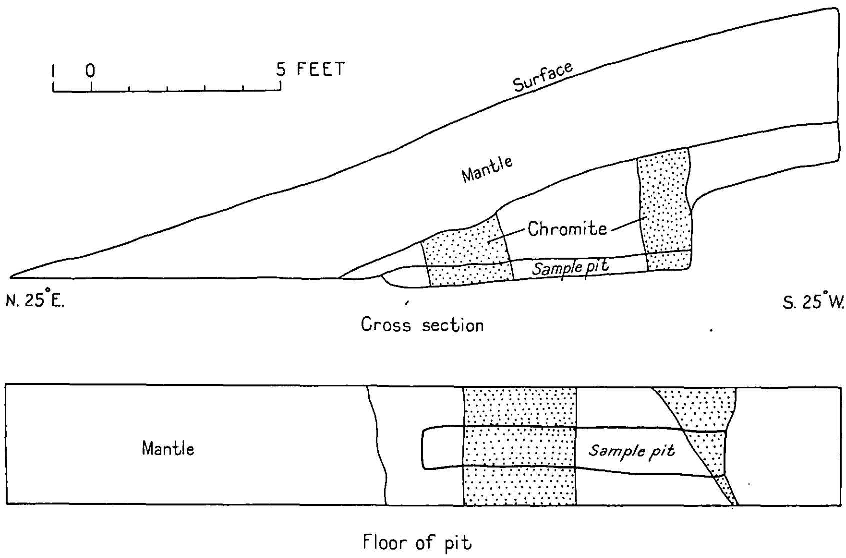


Figure 60.--Plan and cross section of pit D-7, Majestic claim.

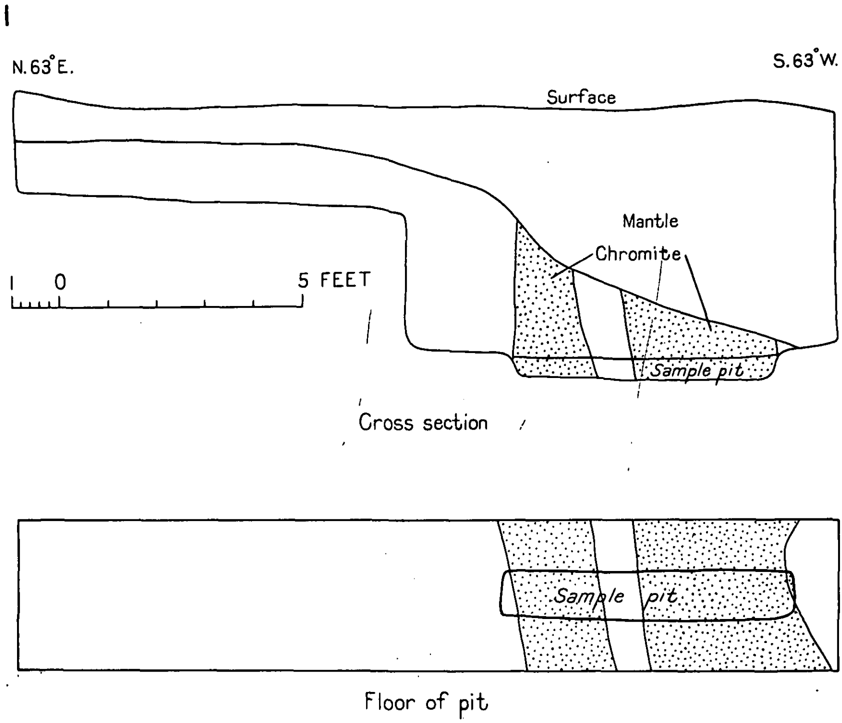


Figure 61.--Plan and cross section of pit D-8, Majestic claim.

near the divide. The main chromite layer is somewhat below, or south of, the middle of a zone of serpentinized harzburgite nearly 1,000 feet wide. Chromite is a common accessory in the

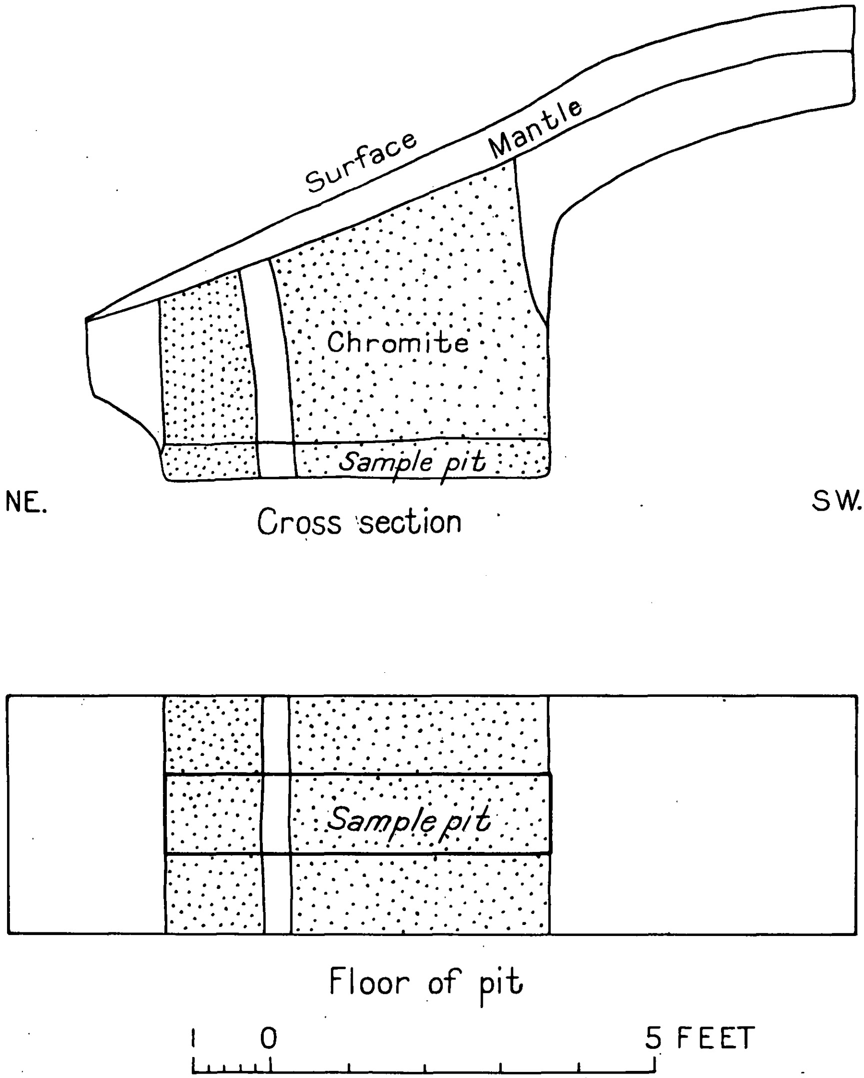


Figure 62.--Plan and cross section of pit D-15, Majestic claim.

harzburgite but probably does not make up more than 2 percent of it by weight. North of the harzburgite zone no chromite was seen, but the bronzitite that borders the harzburgite contains a green diopside similar to one that elsewhere in the complex contains chromium.[25/] The country rock on the south side of the chromite band at the divide is a remarkably coarse grained, serpentinized poikilitic harzburgite containing crystals of bronzite as much as 8 inches in diameter and light-colored interstitial material that is probably altered feldspar. Some of this rock appears pegmatitic in mode of occurrence as well as in texture.

The rock on the north side of the main chromite layer is also serpentinized poikilitic harzburgite but a little finer grained on the whole than that on the south side. Pegmatitic streaks are common in the ore, particularly near the south or footwall side.

Both above and below the main chromite horizon are other bodies of basic pegmatite, which contain bronzite, diopside, and plagioclase. Small crystals of chromite are irregularly distributed through the plagioclase and diopside. The outlines of the pegmatite bodies are irregular and are usually not parallel to the banding of the complex.

Big Seven claim.--The Big Seven claim is located on the steep slope of the Little Rocky Creek-Stillwater divide at the edge of Nye Basin. Exposures in the eastern part of the claim are fairly good, but west of the Big Seven adit they are very poor. No chromite was found west of the adit, although long trenches were dug in search of it. The main chromite layer, which has an average width of 6.3 feet, has been proved for a linear distance of 500 feet. It has much the same character here as on the Majestic claim except that it contains less disseminated ore and, therefore, a somewhat larger percentage of chromite. (Figs. 63 and 64.) It is offset by several faults.

25/ Hess, H. H., personal communication.

Below the Big Seven adit the chromite is displaced by a fault along the side of the hill, the course of which is followed by a natural trench. On both sides of the fault the country rock is highly serpentinized and in places is sheared. The long trenches dug by the Bureau of Mines party west of the

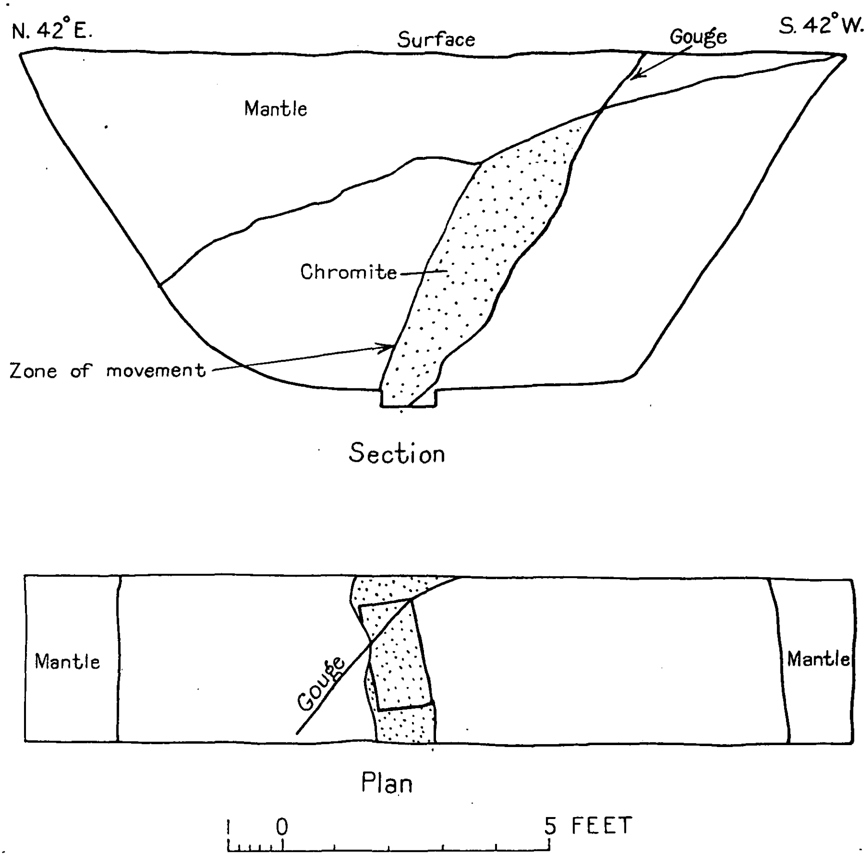


Figure 63.--Plan and cross section of pit D-23, Big Seven claim.

fault showed altered bronzitite except at the north end, where some serpentinized harzburgite has been exposed. The chromite layer has apparently been offset along this fault 200 feet or more to the north, but as the slope is covered with rubble its continuation has not been proved.

The chromite layer should continue westward, but owing to increasing cover in that direction it will be difficult to trace.

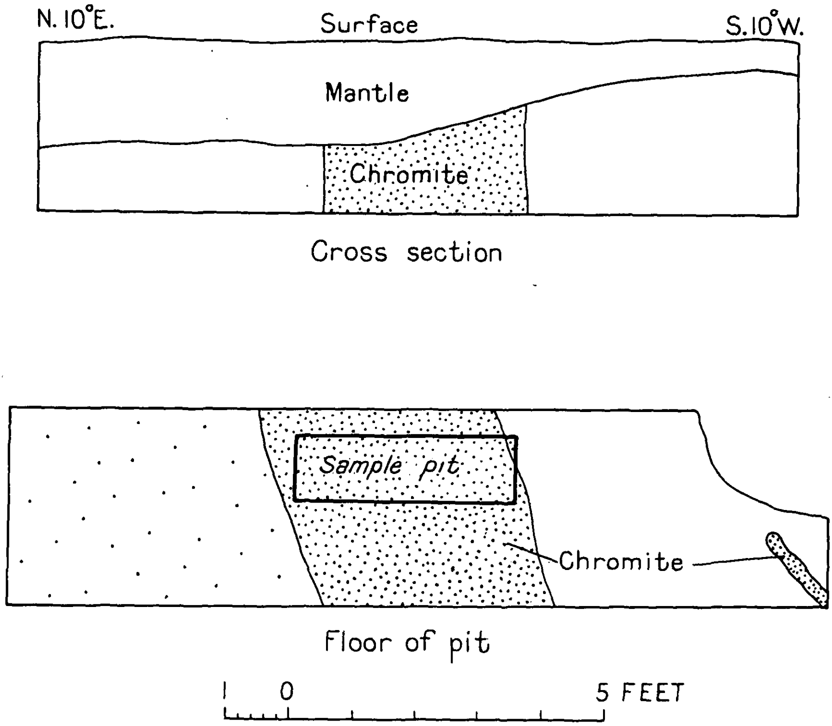


Figure 64.--Plan and cross section of pit D-25, Big Seven claim.

Claims on west slope of Stillwater Valley

Time was not available for detailed mapping on the west slope of the Stillwater Valley, but 10 days was spent in reconnoitering that area.

A ridge of granite extends into the Stillwater Valley from the west. The ultramafic zone is narrow here, but whether it has been cut into by the granite or was originally narrow cannot be determined, because outcrops of the complex are lacking in the valley near the ridge. On the west side of the valley, upstream from the ridge, is a large area of the metamorphic floor of the complex which was not cut out, as it was farther east, by the intrusion of the granite. The metamorphic rocks at their contact with the complex have been shattered and intricately injected with norite. Concentrations of nickel and copper sulphides are well-exposed in Verdigris Gulch.

This area can readily be reached by the automobile road that extends up Stillwater Valley and a private road to a compressor house and cabin near the Mouat sulphide workings, which are on Verdigris Gulch at an altitude of about 5,750 feet. From this private road steep trails extend to several claims held by M. W. Mouat and one by Edward Sampson, Jr. Development on the Mouat claims prior to 1939 consisted of several pits and an adit a few hundred feet long, which is just below the old smelter site, at the west side of the valley.

The west side of the valley is largely mantled with moraine and other surficial deposits, and outcrops are much less common there than in the Little Rocky Creek area. The general course of the chromite zone can be traced, by following float, from the adit nearly to the divide between the main Stillwater River and its west fork. But detailed relations can be seen only here and there, and the wash and moraine proved to be too thick in many places to be penetrated by trenching.

The adit, though several hundred feet long, is apparently all in the loose rubble of an alluvial cone, and the source of a little chromite that was found in the adit is therefore uncertain. Boulders containing streaks and disseminated crystals of chromite occur sporadically on the slope above the adit, but the first outcrop of material in place is on the south side of Mountain View Creek, at an altitude of about 5,880 feet, near the top of a cut bank. This is 100 feet east of the discovery pit of the Charles F. claim, which belongs to M. W. Mouat. The discovery pit is not in bedrock, but in this 100 feet there are several apparent outcrops showing chromite streaks and a boulder 10 feet in diameter that contains 6 chromite seams from 1 to 4 inches thick an inch to 4 feet apart, between which there is some disseminated chromite.

Streaks of chromite from a few inches to a foot wide can be found at various places on the slope above this pit, marking the general continuity of the chromite-bearing zone, but trenching did not expose chromite in place below an altitude of 7,670 feet on the ridge south of Mountain View Lake. From this altitude two chromite-bearing zones can be traced westward for several hundred feet. The lower one ranges from 5 to 12 feet in width; the upper one, 250 feet farther north, is from 1.5 to 6 feet wide. Both consist of layers of chromite-rich rock separated or bordered by layers of chromite-rich harzburgite. These zones strike N. 60°-70° W. and dip 60°-80° NE. Irregular streaks and patches of chromite can be found southeast of the main zones for a distance of nearly 1,000 feet.

The strike and dip of the two zones, if projected eastward, would apparently connect them with the previously mentioned outcrops lower down on the slope. Two similar zones, however, lie north of the projected line in the cliffs about 1,000 feet west-southwest of Mountain View Lake, on the north side of the ridge that separates the Mountain View drainage from that of Verdigris Gulch. Near the base of these cliffs is a wide zone of chromite-rich layers alternating with harzburgite containing disseminated chromite. In one measured section there is a width of 52 feet that contains 17 layers very rich in chromite from 1 inch to about 2 feet wide alternating with harzburgite containing much disseminated chromite, but most of the chromite is concentrated in a zone ranging from 8 to 20 feet in width. About 200 feet west of this zone and higher in the cliffs is a zone of chromite-rich layers and disseminated chromite ranging in width from 3 to 6.5 feet. These two zones can be followed for about 800 feet. At the southwest or upper end, some 300 to 400 feet from the crest of the ridge, the strike of the zones is N. 75°-80° E., and their dip is 60°-70° NW. Above this point they disappear under slide rock, and they do not appear on the other side of the ridge. Downhill to the northeast the strike swings to N. 10°-15° E. and the chromite disappears under talus and wash in the gulch that runs into Mountain View Lake from the west. North of the lake the contact of the ultramafic and banded zones strikes approximately west.

The relation of this rich ore exposed in the cliff to the chromite farther south, on the ridge and beyond, is not known. The fact that the ore in the cliff strikes at right angles to the contact between the ultramafic and banded zones to the north and disappears to the south is hard to explain. It may be the result of deformation before the complex was completely consolidated, or it may be due to later faulting. The same question arises in regard to some chromite bands near Iron Mountain, several miles to the west, which are also at a large angle to the strike of the ultramafic zone.

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