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UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
JAMES BOYD, DIRECTOR

REPORT OF INVESTIGATIONS

INVESTIGATION OF CHROMITE DEPOSITS OF THE STILLWATER
COMPLEX, STILLWATER AND SWEETGRASS COUNTIES, MONT.



BY

N. L. WIMMLER

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By N. L. Wimmer^{2/}

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^{1/} The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Report of Investigations 4368."

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INTRODUCTION AND SUMMARY

The chromite deposits along the Stillwater complex in Stillwater and Sweetgrass Counties, Mont., have at various times been studied and reported on by the Federal Geological Survey, the Montana Bureau of Mines and Geology, other Government agencies, and private interests. Several of the deposits were explored to a small extent by the owners during the World War of 1914-17, but no production resulted.

The importance of these deposits and the urgent necessity of developing large domestic sources of chromite were realized shortly before the beginning of the recent World War. These deposits were therefore investigated and developed by Government agencies and, as a result, now afford the largest known reserves of chromium in the United States.

In 1939, under the authority of the Strategic Minerals Act, the Bureau of Mines and the Geological Survey made preliminary investigations of these deposits. As a result, the Bureau of Mines conducted an extensive program of trenching, diamond core drilling, and sampling. This work was begun in August 1939 and continued to April 1943. The Bureau of Mines also performed numerous metallurgical tests on the beneficiation of the chromite ores and concentrates and for the production of chromium metal therefrom. Research continues as a means toward utilizing these ores.

In June 1941, the Anaconda Copper Mining Co., as agent for the Government, started underground development of the Benbow and Mouat deposits. Large camps were built, and milling plants were constructed there and operated. Some development also was done at the Gish property. These operations were closed in 1943, for by that time it was again possible to import high-grade chromite ores.

The Bureau of Mines has now undertaken a series of investigations of the mining industry in and adjacent to areas to be served by the hydroelectric power plants to be constructed by the Bureau of Reclamation in the Missouri River Basin.

This report on the chromite deposits of the Stillwater complex is one of a series dealing with the mineral resources of Montana, particularly within a 150-mile radius of the Hardin-Yellowtail dam and reservoir site on the Big Horn River, near Hardin, Big Horn County, Mont. It provides factual information and data contained in numerous unpublished reports on the Bureau of Mines investigations and includes a description of the operations conducted by the Anaconda Copper Mining Co.

ACKNOWLEDGMENTS

Preliminary Bureau of Mines examinations of the Benbow and Mouat-Sampson deposits were made by Paul T. Allsman.^{3/} Other deposits were given preliminary examination by E. W. Newman.^{4/} The Bureau's trenching and drilling program was conducted mainly under the direction of Paul T. Allsman. During different periods, the projects were directly supervised by J. J. Naughten, J. N. East, Jr., E. W. Newman, R. D. O'Brien, R. N. Roby, and E. H. Sharp. Special investigations were made later under the direction of S. H. Lorain, chief of the Albany (Oreg.) Branch, Mining Division.

The Federal Geological Survey cooperated with the Bureau of Mines during its preliminary examinations, and during its trenching and drilling program, by preparing geologic maps and conducting geologic studies. The earlier geologic studies of Dr. J. W. Peoples and Dr. A. L. Howland of the Survey were of much help to the investigations.

The Bureau of Mines makes special acknowledgment for the helpful cooperation of the following property owners: B. E. Berg of Livingston, H. G. McClain of Columbus, C. G. Rich of Dean, M. W. Mouat of Nye, H. W. Parcells of Columbus, and W. A. Taylor of Helena; as well as to officials of the Anaconda Copper Mining Co. and to various Federal agencies for their cooperation during the work and for providing essential information on their operations subsequent to that of the Bureau of Mines.

LOCATION AND ACCESSIBILITY

The Stillwater complex of igneous rocks is exposed along the northern margin of the Beartooth Mountains in Stillwater and Sweetgrass Counties, Mont.;

^{3/} Chief, Salt Lake City Branch, Mining Division, Bureau of Mines, Salt Lake City, Utah.

^{4/} Newman, E. W., mining engineer, Bureau of Mines, Salt Lake City, Utah.

It is reported to extend also into Park County. That part of the ultramafic zone which contains the chromite deposits under consideration, extends northwesterly for about 23 miles from sec. 31, T. 5 S., R. 16 E., about 1 mile easterly of Little Rocky Creek, to sec. 14, T. 4 S., R. 12 E., at Boulder River (fig. 1). This area lies between latitude $45^{\circ}20'$ and $45^{\circ}30'$ north, and longitudes $109^{\circ}45'$ and $110^{\circ}13'$ west.

The location of the various properties are shown in figure 2 to be as follows:

Property or area	County	Sec.	Twp.	R.
Benbow	Stillwater	30,31	5 S	16 E
Nye Basin (Big Seven)		25	5 S	15 E
Nye Basin (Alice)		25,26	5 S	15 E
Nye Basin (Lip)		23	5 S	15 E
Mouat-Sampson		22	5 S	15 E
Initial	Sweetgrass	19,20	5 S	15 E
Blue Bird		23,24	5 S	14 E
Taylor-Fry-Tuttle		22,23	5 S	14 E
Iron Mountain (Chrome group)		17,18,19,20	5 S	14 E
East Boulder River (Chrome Queen) ...		13	5 S	14 E
East Boulder Plateau (Champion group)	do.	3	5 S	13 E
Gish		32,33	4 S	13 E
		14,23,24,25	4 S	12 E

The Benbow and Mouat-Sampson properties are accessible from Columbus, Mont., by oiled roads via Absarokee. Columbus is on the main line of the Northern Pacific Railroad and on U. S. Highway 10; it is the principal supply and shipping point for the district (fig. 1). The Gish property, at the western end of the Stillwater complex, is reached from Big Timber, Mont., by U. S. Highway 10 and graveled road. The Initial, Blue Bird, and Taylor-Fry areas are accessible from the Mouat mine camp partly by steep trails and partly by forest road. Other areas can be reached only by trail. A tabulation of the distances between principal points and the altitude at the destination follows:

From	To	Distances, miles	Altitude (approx.)	Travel via
Columbus, Mont.	-	-	4,200	N.P.R.R. Highway 10
Columbus, Mont.	Benbow mill camp	35	5,900	Oiled road
Benbow mill camp	Benbow mine camp	7	8,400	Graveled road
Columbus	Mouat mill camp	44	5,050	Oiled road
Mouat mill camp	Mouat mine camp	4	6,800	Graveled road
Benbow mine camp	do.	28	6,800	Oiled and graveled road
Benbow No. 4 adit	Mouat mill (airline)	3-1/2		Steep trail
Mouat mine camp	Initial area	9	8,500	Steep trails and forest road
Mouat mine camp	Bluebird area	7	8,000	Steep trails and forest road
Mouat mine camp	Taylor-Fry area	8	6,800	Truck road and trail
Big Timber, Mont.	Gish area	33	5,500-6,500	Highway 10 and graveled road

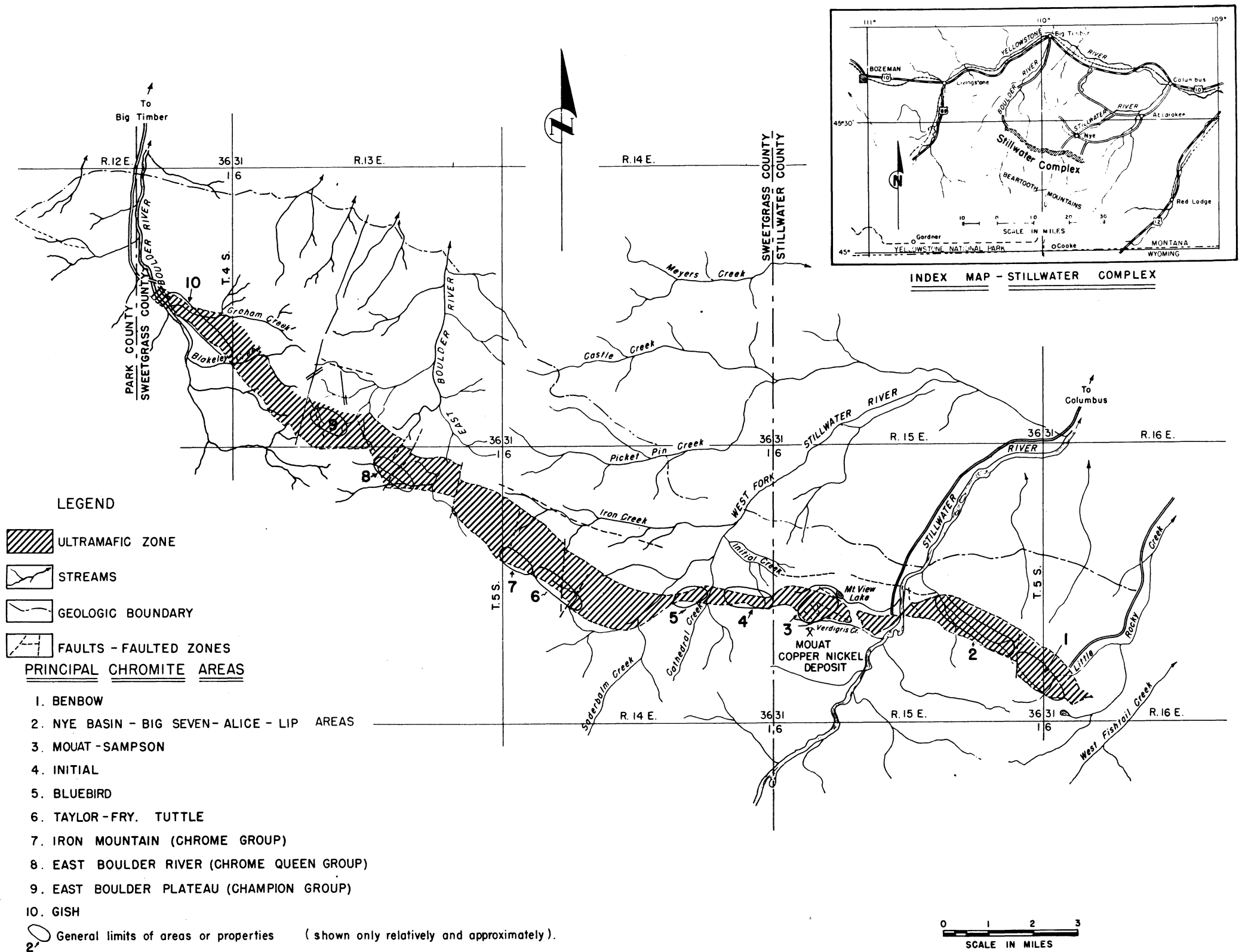


Figure 1. - Stillwater complex, showing ultramafic zone-location of principal chromite deposits, Stillwater and Sweetgrass Counties, Mont.

HISTORY AND PRODUCTION

The occurrence of chromite along the Stillwater complex in Stillwater and Sweetgrass Counties, Mont., was first known more than 60 years ago. It was, however, not until the war demand of 1917 and 1918 that some of the deposits were actively explored, but no ore shipments were made. When the war demand ceased, little further exploration was done except at the Benbow property, which in 1929 was prepared for mining operation. Financial uncertainties in that year caused its suspension. The seven claims were patented, however, in 1933.

The Mouat and Benbow chromite deposits were first examined by Paul T. Allsman, a Bureau of Mines engineer, in July 1939. As a result, the Bureau of Mines started extensive investigations of these deposits in August 1939. Subsequently eight other chromite deposits or areas along the Stillwater complex were investigated by the Bureau of Mines.

As a result of threatened disruption of foreign chromite imports early in the war, the Anaconda Copper Mining Co., as agent for the Government (Metals Reserve Corporation), began development at the Benbow property in June 1941. Soon afterward it started development of the Mouat-Sampson properties. In the spring of 1942, the Gish property was included in the development program. More than 12 million dollars was expended by the Government on camps, plants, equipment, development, operation, etc., at these three properties. The Benbow and Mouat-Sampson properties were brought into production. Although the chromite concentrates produced were not of high quality, they would have been of great value had the emergency continued. These operations were, however, closed by Government orders in 1943 after the sea lanes had been reopened and high-quality imported ore again became available. The Government's leases on these properties were cancelled later and numerous buildings and many items of equipment and supplies, largely from the Benbow property, have been removed and sold; other items have been declared surplus.

Production data on the Anaconda Copper Mining Co. operations at the Benbow and Mouat-Sampson properties are summarized as follows:

	<u>Benbow</u>	<u>Mouat-Sampson</u>
Ore mined or broken, tons	224,700	183,200
Average Cr ₂ O ₃ content, percent	18.4	21.64
Ore milled, dry tons	186,369	77,696
Average Cr ₂ O ₃ content, percent	18.34	19.26
Concentrates produced, dry tons	72,566	29,538
Average Cr ₂ O ₃ content of concentrates, percent,	41.46	38.81
Period of mill operation	March 1, 1942 to June 21, 1943	April 1, 1943 to Oct. 29, 1943
Days mill operated	427.7	130.43

The Anaconda Copper Mining Co. also mined a small quantity of ore at the Gish property during its limited exploitation in 1942. None of the Gish ore was milled.

PHYSICAL FEATURES AND CLIMATE

The Stillwater complex occupies a region of high relief composed of plateaus 9,000 to 12,000 feet in altitude and cut to depths of 3,000 to 5,000 feet by northward flowing streams. The principal streams are the Stillwater and Boulder Rivers, with tributaries thereof, all draining into the Yellowstone River. The tops of the plateaus form a rolling plain, with monadnocks rising 1,000 feet or more above the general level. Pleistocene glaciation has formed hanging valleys and left much glacial drift. Numerous small glaciers remain, and large areas of marsh and occasional small lakes occur, both on the plateaus and in the valleys.

Heavy snowfalls, high winds, and low temperatures prevail during the winter. Snow slides and deep drifts handicap communications well into late spring. From June to about October the climate is moderate and generally pleasant. The roads to the Benbow and Mouat-Sampson mines and mills have generally been kept open during the winter. During the operation of these properties the Forest Service maintained a rotary snow plow and several heavy road patrols for clearing the roads.

TIMBER AND WATER

Timber suitable for mine support is generally lacking in the near vicinity of the mines. Good stands of Douglas fir, lodgepole pine, white-bark pine and Engleman spruce are found, however, within 25 to 40 miles of the deposits. The Anaconda Copper Mining Co. operated a sawmill on Picket Pin Creek during the latter stages of its mine operations. The delivered cost of this rough lumber is reported to have been about \$80 a thousand board feet.

An abundance of water is available for all mine and mill operation. The plateaus, however, do not afford a steady supply. During most of the year water must be pumped from the main streams.

POWER

Power for the mining and milling operations at the Benbow and Mouat-Sampson mines was provided by the Montana Power Co. from its hydroelectric plant at Mystic Lake. The air-line distance from this plant to the Benbow and Mouat mines is, respectively, 9 and 13 miles northwest. This plant has a continuous capacity of 6,000 kilowatts, with a peak load of 11,500 kilowatts.

Sites for water-power development are available on the Stillwater River above the Mouat property, on Boulder River, and on some of the smaller streams. The average annual run-off of the Stillwater River above Woodbine Falls is reported to range from 90,000 to 272,000 acre-feet.

The Montana Power Co. Mystic Lake power rates are scheduled as in table 1.

In addition to the above rates, a charge of \$1 per horsepower per month, based on the demand load, is made for alternating-current motors.

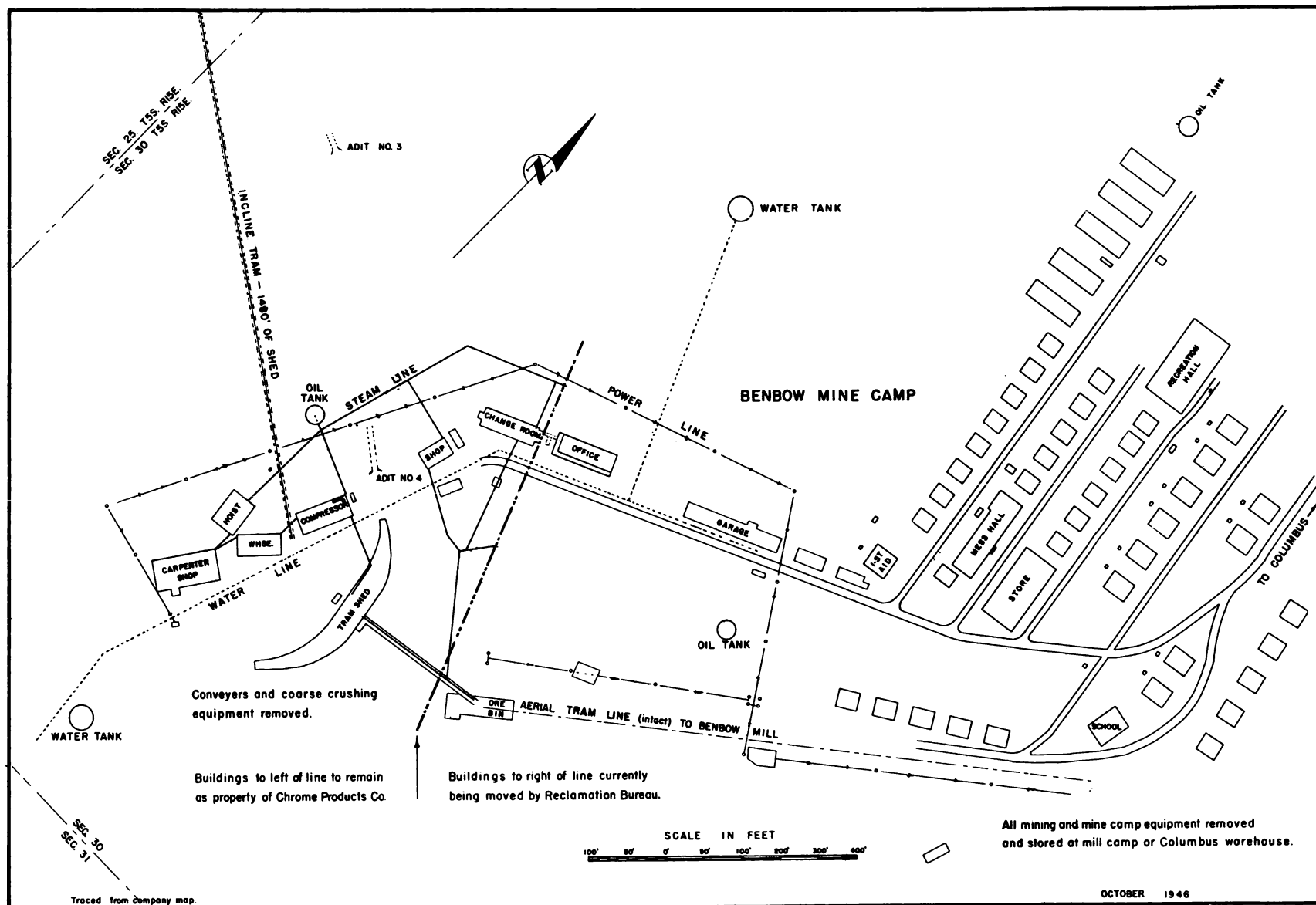


Figure 2. - Plan of mine camp, Benbow mine.

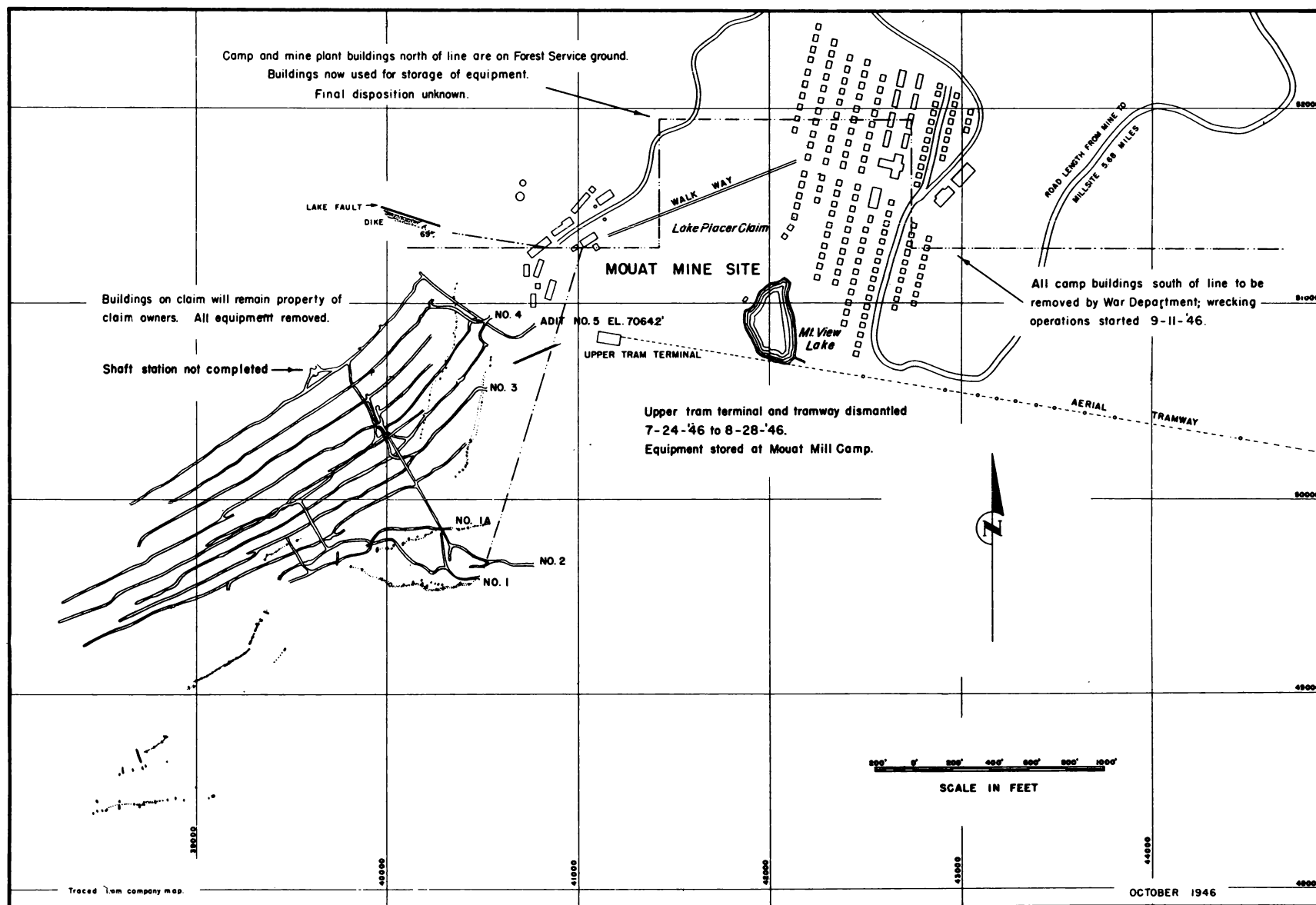


Figure 3. - Plan of mine plant and underground workings, Mouat mine.

TABLE 1. - (Schedule G-41)

Horsepower	Rate per kw.-hr.	Horsepower	Rate per kw.-hr.
1	\$0.028	75	\$0.0098
2	.027	100	.0087
3	.026	125	.0080
5	.025	150	.0074
7-1/2	.023	175	.0071
10	.021	200	.0068
15	.019	300	.0061
20	.017	500	.0055
25	.016	750	.0051
35	.014	1000	.0050
50	.0116	2000	.0048

The consumption and cost of this power at the Benbow operations during April 1943 (an average month) and at the Mouat-Sampson operations during August 1943 (a month of highest production) are reported in table 2 as follows:

TABLE 2

Plant	Power demand		Power consumed, meter reading, kw.-hr.	Cost per kw.-hr. metered	Cost per hp. demand	Total cost per month
	Kw.	Hp.				
Benbow mill	544.00	729.32	285,600	\$0.005	\$1.00	\$2,156.95
Benbow mine	560.00	750.67	244,800	.005	1.00	1,974.40
Mouat mill	979.00	1,313.00	502,757	.0048	1.00	3,726.23
Mouat mine	1,016.00	1,361.93	521,493	.0048	1.00	3,865.10
Totals	3,099.00	4,154.82	1,554,650		1.00	\$11,722.68

LABOR AND LIVING CONDITIONS

The district is sparsely settled; consequently practically all labor, whether skilled or unskilled, must be recruited from large mining centers such as Butte, Mont. As this had to be done during the operations by the Anaconda Copper Mining Co., the Butte scale of wages was established. As of August 1943, the wages paid for construction work ranged from \$5.75 to \$12 for an 8-hour shift, or \$0.72 to \$1.50 an hour, according to the job and skill involved. The scale for work in the concentrating plants ranged from \$6.75 to \$8.25 an 8-hour shift and for mine labor from \$6.75 to \$7.50. Miners were paid \$7, muckers \$6.75, timbermen \$7, and powdermen \$7 for an 8-hour shift. Wages at Butte have since been increased by more than 35 percent.

Housing facilities and boarding houses were built at both the mine and mill at the Benbow and Mouat-Sampson properties (figs. 2, 3 and 4). These camps provided excellent housing for the employees and families and rooms and board for those requiring them. Many of these houses and other accommodations have now been removed and disposed of by the War Assets Administration.

PROPERTY AND OWNERSHIP

The number of claims included in the various properties investigated by the Bureau of Mines and their ownership at that time were as follows:

Property	Number of claims			Ownership
	Pat.	Located	Lode Others	
Benbow	7	-	2 millsites	Chromium Products Corp., Livingston, Mont.; B. E. Berg, Secretary.
Nye Basin..... (Big Seven Fault, Alice, Lip)		various		Various locations claimed by M. W. Mouat et al, Chromium Products Corp., T. C. Barker, and H. Waldo.
Mouat-Sampson.....	3	18	2 tunnel sites	M. W. Mouat et al, Nye, Mont.; Edward Sampson, Princeton, N. J.
	-	2	-	
Initial.....		2	-	M. L. Parcells, R. W. Whipple, R. Lundy, and W. C. Newcomb.
Bluebird.....	-	3	-	M. L. Parcells, W. E. Newcomb, R. W. Whipple, R. Lundy, and F. Hawks.
Taylor-Fry.....	-	21	1 placer 1 millsite	B. Fry and W. A. Taylor
Tuttle.....	-	4		S. J. Tuttle
Iron Mountain..... (Chrome group)		11		Montana Chrome Corp.
East Boulder River.. (Chrome Queen group)		9		do.
East Boulder Plateau (Champion group)		3	-	D. F. Whittaker, Great Falls, Mont.
Gish	14		-	Purchased by R. G. Taylor, Billings, Mont., May 1945

The Mouat-Sampson property was leased in 1941 for a 10-year period by the Metals Reserve Corporation, acting as agent for the Reconstruction Finance Corp. This lease was canceled by the Government on February 1946. The Mouat mill and the mill camp were built on land obtained by condemnation by the Government and quit claim deed from M. W. Mouat. Both mill and mill camp (fig. 4) were intact and in good condition in 1946, but the final disposition of the buildings and equipment are not of record. The Mouat mine plant (fig. 3) is on the mining claims and on Forest Service land. The mine-plant buildings on the mining claims probably will remain as possessions of the claim owners. About 80 percent of the mine-camp buildings were on the Lake placer claim held by M. W. Mouat; these have been removed by the Government. The aerial tram and all equipment in the mine-plant buildings, other than those on Forest Service land, also have been removed and stored on Government-owned property.

The Benbow property was leased by the Government under a similar arrangement. The lease was canceled, however, before its expiration date. The mill building remains intact. The mill-camp buildings have been removed. All heavy equipment and much other equipment have been removed from the mill and either sold or stored. The 3-1/2-mile aerial tram remains intact. Plans for final disposition of the tram and mill are not on record. All mine-plant buildings (fig. 2) on company-owned land will remain the property of the Chromium Products Corp., which also has acquired the shaft head frame and all track and pipe installed in the mine. All other mine-plant and mine-camp buildings were removed.

The Gish property also was leased by the Government. This lease was canceled several years later. The buildings erected by the Government, and all machinery and equipment, have been removed.

No mine plant, buildings, or housing facilities are present at any of the other properties along the Stillwater complex.

MINE WORKINGS

The surface trenching, diamond core drilling, and underground work done by the Bureau of Mines during its investigation of the chromite deposits along the Stillwater complex are described elsewhere in this report. Before the Bureau of Mines project only a relatively small amount of underground work had been done by the owners on the Benbow, Mouat-Sampson, and Gish properties and only a few cuts and test pits had been made on the other properties.

The Anaconda Copper Mining Co., as agents for the Government during 1941, 1942, and 1943, conducted extensive underground development and also completed a considerable amount of diamond core drilling. A summary of the work accomplished by the Anaconda Copper Mining Co., in linear feet, follows:

Mine	Drifts, crosscuts and laterals	Intermediate workings	Raises and shafts	Total underground workings	Diamond drilling
Mouat	29,804	335	8,519	38,658	3,218
Benbow	25,260	11,630	9,897	46,787	2,638
Gish	3,800	-	265	4,065	770
Totals	58,864	11,965	18,681	89,510	6,626

More detailed accounts of the mine developments are given in this report under separate property headings.

GENERAL GEOLOGY

Extensive detailed geologic surveys and studies of the Stillwater complex have been made and reported by the Federal Geological Survey. The most recent Survey publication available on the subject is the report by Peoples and Howland.^{5/}

^{5/} Peoples, J. W., and Howland, A. L., Chromite Deposits at the Eastern Part of the Stillwater Complex, Stillwater County, Mont. Geol. Survey Bull. 922-N, 1942, pp. 371-416.

The Beartooth Range may be described, geologically, as a huge, asymmetrical, east-west anticline. For 30 miles along the edge of the dissected upland, a belt of layered, ultrabasic igneous rocks, composed chiefly of olivine and pyroxene 1 to 5 miles wide, lies between the sharply upturned Paleozoic and Mesozoic sedimentary beds on the north and the pre-Cambrian granite and ancient sediments on the south. The edge of the mountain front is marked by thrust faults dipping southward. This series of layered igneous rocks has been named the Stillwater complex. It is about 16,000 feet thick; the top of it has been eroded.

The Stillwater complex has been classified into four main zones. The ultramafic zone, in which the chromite deposits occur, is in the lower part of the Stillwater complex between a basal zone of diabasic norite and an overlying zone of banded norite, anorthosite, and olivine gabbro.

The most remarkable feature of the Stillwater complex is the arrangement of the various rock types in layers. These layers probably were formed in a nearly horizontal position but since have been tilted and faulted into their present position. For most of the length of the complex the layers now strike between N. 60° W. and N. 80° W. In several localities along the ultramafic zone the strike deviates widely and is far from parallel to the contact with the banded zone above it. Near the west end of the complex, the dip ranges from 30° to 60°, but at the east end the dip is almost vertical, the chromite layers dipping to the north in some places and to the south in others.

This ultramafic zone itself, as mapped (fig. 1) between the Benbow property at the east and the Gish property at the west, is about 23 miles long and about 1/4 to 1 mile wide. It is composed essentially of olivine and pyroxene and of other rocks that contain these minerals. It is less conspicuously banded than the overlying zones, but there is a broad, parallel arrangement of the rock types.

The principal rock types of this zone are bronzitite (a variety of pyroxenite), granular and poikilitic harzburgite, and basic pegmatites. Bronzitite is composed chiefly of pyroxene bronzite. It is a massive tough rock that occurs both north and south of the chromite horizon. It contains very little chromite, although thin seams 1 to 2 inches thick have been found at a contact between bronzitite and harzburgite. The granular harzburgite is somewhat similar to bronzitite but contains an appreciable amount of olivine. Some is altered to serpentine. Chromite is present locally as an accessory mineral but only in small amounts. Poikilitic harzburgite differs little from the granular harzburgite in composition but usually contains a larger proportion of olivine and serpentine. Bronzite in this rock occurs in skeleton, or poikilitic, crystals containing rounded grains of olivine. Much of it is altered to serpentine. It occurs on both sides of the chromite seams and in places merges gradually into an almost massive chromite ore. The basic pegmatite dikes that cut these formations are composed usually of a much fractured, fine-grained green rock of gabbroic or dioritic composition.

THE DEPOSITS

The chromite deposits show many variations in size and form, but all deposits of any consequence are associated with the poikilitic harzburgite. Usually they form steeply dipping bands and lenses parallel to the general layering of the complex in the same general horizon. They do not occur, however, as a continuous body but generally as a series of overlapping lenses or segments. The deposits may be of nearly massive chromite, or they may be banded, with disseminated chromite between the bands or extending into the walls. The richest streaks of ore may contain about 85 percent of chromite by volume, but these streaks grade into very low-grade material. This chromite mineralization may range in width from only a few inches or a few feet to 50 feet or more. On the other hand, the widths of the chromite bands that are minable as ore range from a few feet to about 12 feet. The chromite-bearing horizon has many offsets owing to displacement along northward-striking faults. Many other apparent offsets are due to the overlapping of chromite lenses at slightly different horizons.

Numerous shrinkage stopes started from the lower levels of the Mouat mine are untimbered and stand well without timbering. No sloughing of the wall rock has occurred so far in either the stopes or the untimbered draw chutes, but heavier ground is encountered in the vicinity of the faults. Although the formation at the Benbow mine is generally hard, it contains more serpentine than the formation at the Mouat and is more broken and shattered by faults. The numerous dike intersections at the Benbow also cause heavy ground. As a result, more timbering is necessary, and the cost of maintaining the workings will be higher at the Benbow than at the Mouat.

The ore mineral in these deposits is referred to as chromite. Nevertheless its composition differs widely from the theoretical composition of true chromite (FeCr_2O_4 , or 68 percent Cr_2O_3 and 32 percent FeO). A chemical analysis by the Bureau of Mines of a cleaned sample from the Benbow mine is reported as follows:

	Percent
FeO	24.05
Cr_2O_3	46.09
Al_2O_3	23.81
MgO	5.43
SiO_2	1.02
	<u>100.40</u>

The formula for this mineral could be written $(\text{FeMg})\text{O}(\text{Cr Fe Al})_2\text{O}_3$ and could be classed as chromohercynite, which is characterized by abundant Al_2O_3 . It contains only about two-thirds as much chromium as pure chromite, FeCr_2O_4 , and its chromic oxide content therefore cannot be improved above 46 percent by any milling or concentrating processes. This applies to all of the so-called chromite ore from this ultramafic zone.

Numerous tests made on ore and concentrates from various locations have shown a variable but low Cr:Fe ratio. The average Cr:Fe ratios recorded was

1.46 for massive ore containing 34.1 percent chromic oxide and 1.71 for concentrates containing 45.4 percent chromic oxide. The operations at the Benbow and Mouat mills during their relatively short operation (which was largely a period of adjustment), produced concentrates averaging respectively 1.61 and 1.44 in Cr:Fe ratio.

WORK BY THE BUREAU OF MINES - GENERAL

Trenching, Diamond Core Drilling, etc.

The field investigations conducted by the Bureau of Mines were begun August 21, 1939, and, with the exception of several short recesses due to exceptionally difficult conditions imposed by weather, were continued until April 1943. Because of the isolation of some of the areas, it was necessary to clear and reconstruct old trails, build new trails, and establish camps. In total, 10 miles of new trails were built; and 2,304 feet of trenching, 14,407 feet of diamond core drilling, 75 feet of shaft sinking, and 25 feet of crosscutting were accomplished. The total cost of these projects was \$131,000. About 150 tons of ore from various deposits were shipped to the Bureau laboratories at Boulder City, Nev., and Salt Lake City, Utah, for metallurgical tests and ore-dressing experiments.

All trenching was done by pick and shovel, drilling, and blasting, as the terrain did not permit the use of mechanical equipment. All trenches were excavated into the solid formation and continued well beyond the walls of the chromite mineralization. A width of at least 3-1/2 feet was maintained at the bottom. In the Benbow and Mouat areas, channel samples were cut across the chromite exposures in the trenches for a width of 12 inches and a depth of 6 inches, whereby about 100 pounds of material was obtained per linear foot. In the other areas the sample channels were cut 4 inches wide and 2 inches deep, yielding about 12 pounds per linear foot. The length of a channel sample was 5 feet, except where the width of mineralization was less than 5 feet or where narrow bands of higher-grade ore required that the samples be divided into shorter sections. The total number of trench samples taken and assayed was 482.

Diamond core drilling was begun in June 1940 under contracts with the Diamond Drill Contracting Co. and J. L. Havlick, of Spokane, Wash., and Thatcher Bros. of Phoenix, Ariz. Thirty-seven holes were drilled at an average cost of \$3.39 a foot. With the exception of two holes from the No. 5 level of the Mouat-Sampson mine and one hole from the No. 4 level of the Benbow mine, all holes were drilled from the surface. The core recovery was high, except when difficulties were experienced in broken and faulted structures.

Geophysical prospecting was undertaken by Hans Lundberg, Inc., as part of the Bureau's investigations in the upper Nye Basin and Mountain View Lake areas. The results obtained were not conclusive as to the chromite but provided some data that were useful in solving some of the fault and structural problems.

The amount of trenching and diamond core drilling done at the various properties and the sampling data and results at each property investigated are given later in this report under separate property headings.

Metallurgical Testing and Ore Dressing

The Bureau of Mines has for some years been conducting investigations to develop methods for utilizing the Montana chromites. The work has proceeded along three general lines: (1) To develop mechanical methods for concentrating the ores, (2) to develop a simple metallurgical treatment for reducing the iron content in the concentrates to make them suitable for the manufacture of standard ferrochrome; and (3) to develop an electrolytic process for producing pure chromium metal.

Gravity concentration and flotation tests at the Bureau's Salt Lake City laboratory^{6/} showed Montana chromite ores to be amenable to such methods.

Coarse gravity methods, namely sink-float and jigging, were found to be applicable for the rejection of coarse waste and low-grade material as a preliminary step. Optimum results were obtained, however, on the Mouat ores by table concentration of the coarser sizes and flotation of the fines.

Sink-Float: On Mouat ore containing 22.8 percent oxide, it was found that over one-third of the ore, when crushed to minus 2-inch, could be rejected by sink-float and jigging methods with a chromium loss of less than 10 percent, an iron rejection of 25.6 percent, and a silica rejection of over 56 percent. The product, representing 65 percent by weight of the original ore, assayed 29.8 percent chromic oxide, 18.3 percent iron, and 10.2 percent silica. In case of waste dilution in mining, this method of treatment would provide higher mill heads and reduce fine grinding.

Table Concentration and Flotation: Table concentration of ore from the same lot, hydraulically sized after roll crushing to minus 28-mesh with re-treatment of middlings and tailings reground to minus 48-mesh, recovered 88.8 percent of the chromite in a concentrate assaying 40 percent chromic oxide, with a Cr:Fe ratio of 1.22. Magnetic separation of the table concentrates to determine the dilution by magnetite was employed but made little improvement in the Cr:Fe ratio.

A combination method of table concentration and flotation on the ore (31.1 percent of which was ground to minus 65-mesh) recovered 89.3 percent of the chromite in a concentrate assaying 39.8 percent chromic oxide with a 1.23 Cr:Fe ratio.

Ore from the Gish property assaying 13.5 percent chromic oxide and 14.5 percent iron, which contained two types of chrome spinel, was ground to minus 35-mesh. By table concentration with a middling re-treatment, 80.5 percent of the total chromite in the ore was recovered in a concentrate assaying 37.8 percent chromic oxide, with a 1.21 Cr:Fe ratio. The high iron content of the chromium material limited the grade of concentrates obtainable.

^{6/} Batty, J. V., Mitchell, T. F., Havens, R. and Wells, R. R., Beneficiation of Chromite Ores from Western United States: Bureau of Mines Rept. of Investigations 4079, 1947.

Roasting and Leaching: Various smelting tests were first attempted in beneficiating chromite. These tests were based on the fact that iron is easier to reduce than the chromium in the chromite. It was found that, if the ore was roasted under strong reducing conditions at about 1,300° C., the iron portion was reduced to a pseudometallic state, rendering it soluble in dilute acids while most of the chromium remained insoluble.⁷ Removing the iron by leaching with acid leaves the residue richer in chromium and increases the Cr:Fe ratio. This developed larger-scale testing⁸ on chromite concentrates, whereby they were roasted with the addition of some coke in a reducing atmosphere in a rotary kiln. The resulting calcine was then leached with 18 percent sulfuric acid to remove iron. By this treatment, the insoluble residue contained a Cr:Fe ratio of 3.0 and greater - well above that required for the production of ferrochrome.

Hydrometallurgy and Electrolysis: In a further effort to utilize the Montana chromites, the Bureau of Mines is developing a process for electro-winning chromium from chromite ores and concentrates.⁹ Work on this process is progressing at the Bureau's laboratory at Boulder City, Nev. Chromite concentrates produced by the Benbow and Moutat mills are being used in this work. In the electrowinning process, a crude chromic sulfate solution is produced by digesting the finely ground concentrates with cell anolyte, which contains both sulfuric and chromic acids, and additional sulfuric acid. The filtered digest liquor is diluted with spent mother liquor containing ammonium sulfate, and the iron, aluminum, and magnesium are removed by crystallizing them as the respective ammonium sulfate complexes. Crude chrome alum is then produced by aging the chromium sulfate liquor for about 5 days at 30° C. This aging is accomplished on a continuous basis in a standard thickener. The crude alum is removed by centrifuging, and the spent mother liquor is returned to dilute the next digest. Crude alum is recrystallized once to remove the remaining impurities, and the pure alum is dissolved in a small quantity of water along with recovered glauber's salt to produce cell feed solution. The cell feed solution is electrolyzed to yield pure chromium metal and sulfuric acid. The sulfuric acid is returned to the system in the anolyte.

The Bureau of Mines now has an electrowinning-process pilot plant capable of producing 100 pounds of chromium metal a day. Its operation indicates that, with a plant capable of producing 20,000 pounds of chromium a day, this metal will be able to compete on an economic basis with low-carbon ferrochrome and also provide a new economic supply of chromium metal.

Refractory Tests: Refractory tests on Benbow chrome concentrates have been made at the Bureau of Mines Northwest Experiment Station, Seattle, Wash.

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- ⁷/ Dean, R. S., Annual Report of the Metallurgical Division, Fiscal Year 1941: Bureau of Mines Rept. of Investigations 3600, 1941, pp. 41-42.
 - ⁸/ Lloyd, R. R., Garst, O. C. Rawles, W. R., and others, Beneficiation of Montana Chromite Concentrates by Roasting and Leaching: Bureau of Mines Rept. of Investigations 3834, 1946, pp. 1-37.
 - ⁹/ Lloyd, R. R., Rawles, W. T., and Feeney, R. G., The Electrowinning of Chromium from Trivalent Salt Solutions: Trans. Electrochem. Soc., vol. 89, 1946, pp. 443-454.

The concentrates tested contained Cr_2O_3 40.0 percent, Al_2O_3 14.7 percent, total iron calculated as FeO 21.7 percent, MgO 13.8 percent, CaO 0.1 percent, SiO_2 3.8 percent, TiO_2 3.0 percent, loss on ignition + 0.5 percent. Bricks were made of this material in the proportion of 50 percent 14-to 48-mesh and 50 percent -100 mesh, formed at a pressure of 11,000 p. s. i. and fired to cone 30. They had a bulk density of 219 pounds per cubic foot and an apparent porosity of 12.5 percent.

Standard refractory tests on the bricks showed them to have a greater density and a lower porosity than commercial chrome bricks on the market. The laboratory-prepared bricks were superior in load-bearing ability at higher temperatures, had somewhat lower bursting expansions due to iron oxide absorption, and compared favorably to commercial brick in resistance to "slump" at higher temperatures. Nevertheless, the service behavior of refractory brick cannot be predicted from laboratory tests alone. For plant production the addition of a higher-grade ore or dead-burned magnesite would be desirable.

CHROMITE PRODUCTION, IMPORTS, CONSUMPTION, AND PRICES

Chromite domestic production, imports for consumption, and total consumption for the United States for the period 1940 to 1946, as reported by Bureau of Mines Minerals Yearbooks were, in short tons, as follows:

Year	Domestic production	Imports for consumption	Total consumption	
			Tons	Cr_2O_3 , percent
1940	2,982	736,612	562,915	45.0
1941	14,259	1,115,292	800,290	44.3
1942	112,876	981,607	891,952	43.2
1943	160,120	928,576	964,600	43.8
1944	45,629	848,390	848,449	44.1
1945	13,973	914,765	808,120	43.8
1946	4,107	757,391	734,759	43.2

The peak consumption of chrome ores in the United States was reached in 1943, when 964,000 short tons (422,494 short tons chromic oxide) were used. Distribution of this material among the primary consumer's groups in 1943 was as follows:

Group	Percent of total	Ore	
		Short tons	Cr_2O_3 content, percent
Metallurgical	57.6	555,259	48.5
Refractory	29.2	282,178	34.0
Chemical	13.2	127,163	44.7
Total	100.0	964,600	43.8

Market prices (April 1947) for chrome ores and concentrates per long ton were quoted as follows:

Percent Cr ₂ O ₃	Cr:Fe ratio	Price, f.o.b. cars Atlantic ports
48.0	2.8:1	\$36.00 @ \$37.00
48.0	3.0:1	38.00 @ 39.00

The market price of chromium metal, 97 percent grade, at current quotations is \$0.89 a pound for spot transactions and \$0.84 a pound on contract. The demand for the metal at this price is, however, believed restricted to specialized uses. Low-carbon ferrochrome, which chromium metal could probably compete with and perhaps partly replace in the metallurgical industry, is quoted currently at about \$0.23 a pound. Present demand for low-carbon ferrochrome is approximately 50 tons a day. The maximum market that might be developed for chromium metal produced from Stillwater Chromite ores, as far as can now be estimated, probably would not absorb more than about 35 tons a day.

PROPERTIES, MINES, AND MILLS

Benbow Mine

The Benbow property, at the eastern end of the Stillwater complex, was located first in 1918. The Eclipse adit was begun, but all work was soon suspended. The property later was purchased by the Chromium Products Corp. A group of eastern men obtained a bond and lease on the property and in 1929 drove the Eclipse and Majestic adits. This work ceased the same year, and the property lay idle until 1939. The Bureau of Mines started its program of trenching the outcrop on August 21, 1939. The results were so encouraging that diamond core drilling was undertaken. Canadian interests acquired the property on a sales contract in 1940 and under the direction of F. E. Weldon drove a new adit over 1,400 feet long, starting near trench C-17 (fig. 5). These interests suspended development when the Anaconda Copper Mining Co. took over as agent for the Government in June 1941.

The Deposits

The general geology of the Stillwater complex, and particularly the ultramafic zone in which the chromite deposits occur, has been described in preceding pages of this report. Geologic mapping 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 faults, but many others are due to overlapping of chromite lenses at slightly different horizons. About 150 feet west of the Black Rock adit the ore lens 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.

The chromite bands or lenses differ in character along the strike. Near the east end of the Benbow claims, chromite occurs over a width 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

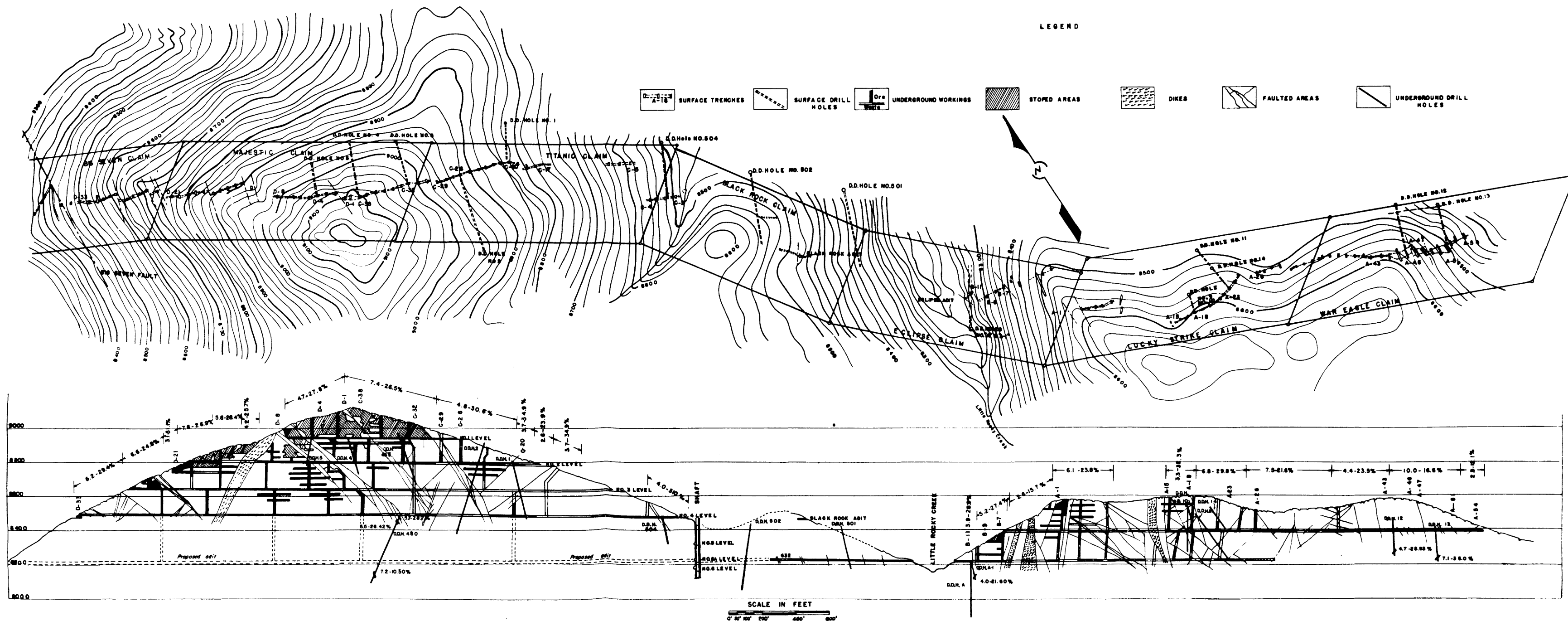


Figure 5. - Surface plan and longitudinal projection of Benbow chrome deposit, Stillwater County, Mont.

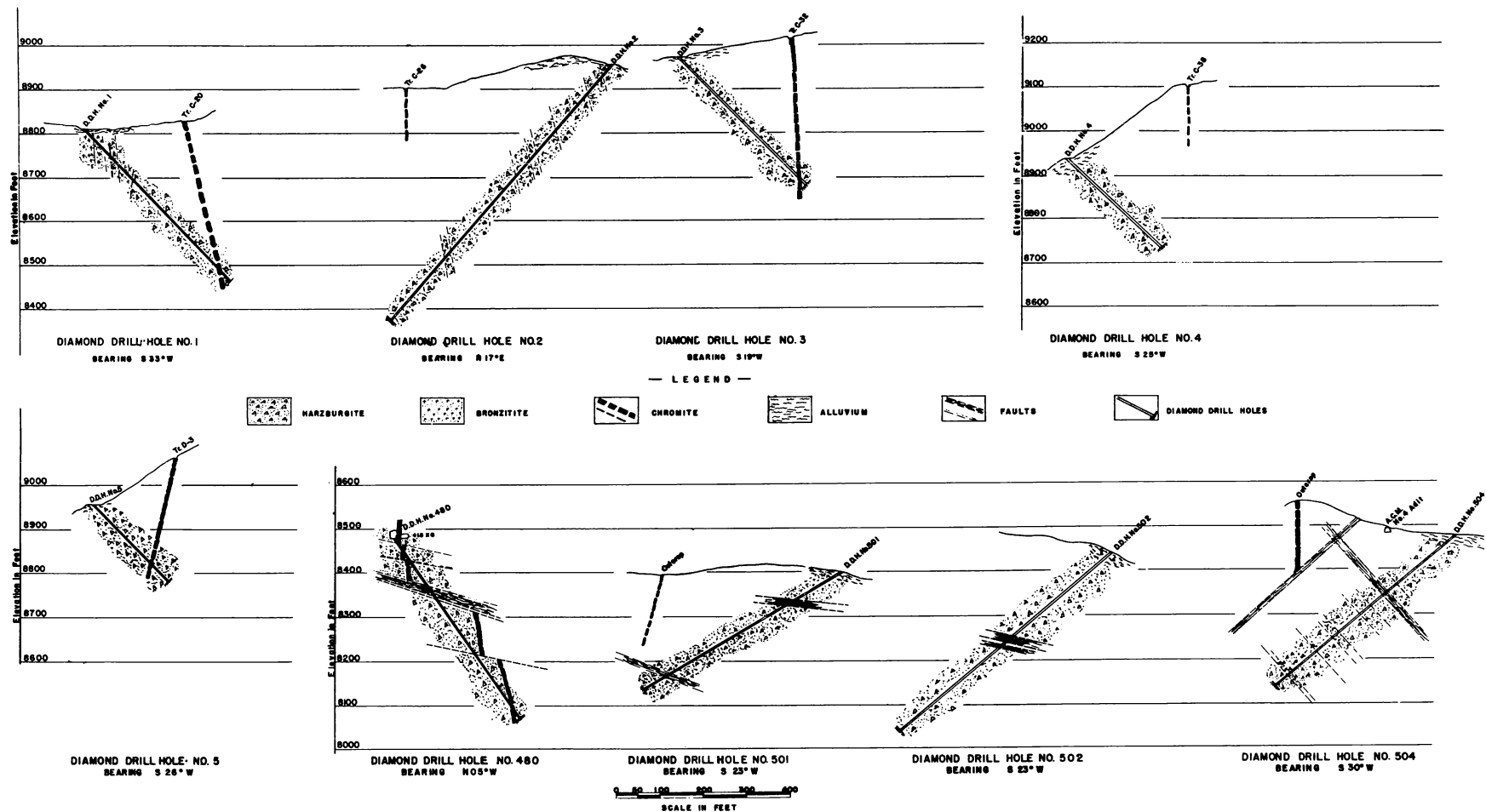


Figure 6. - Diamond-drill-hole sections, Benbow area, Stillwater County, Mont.

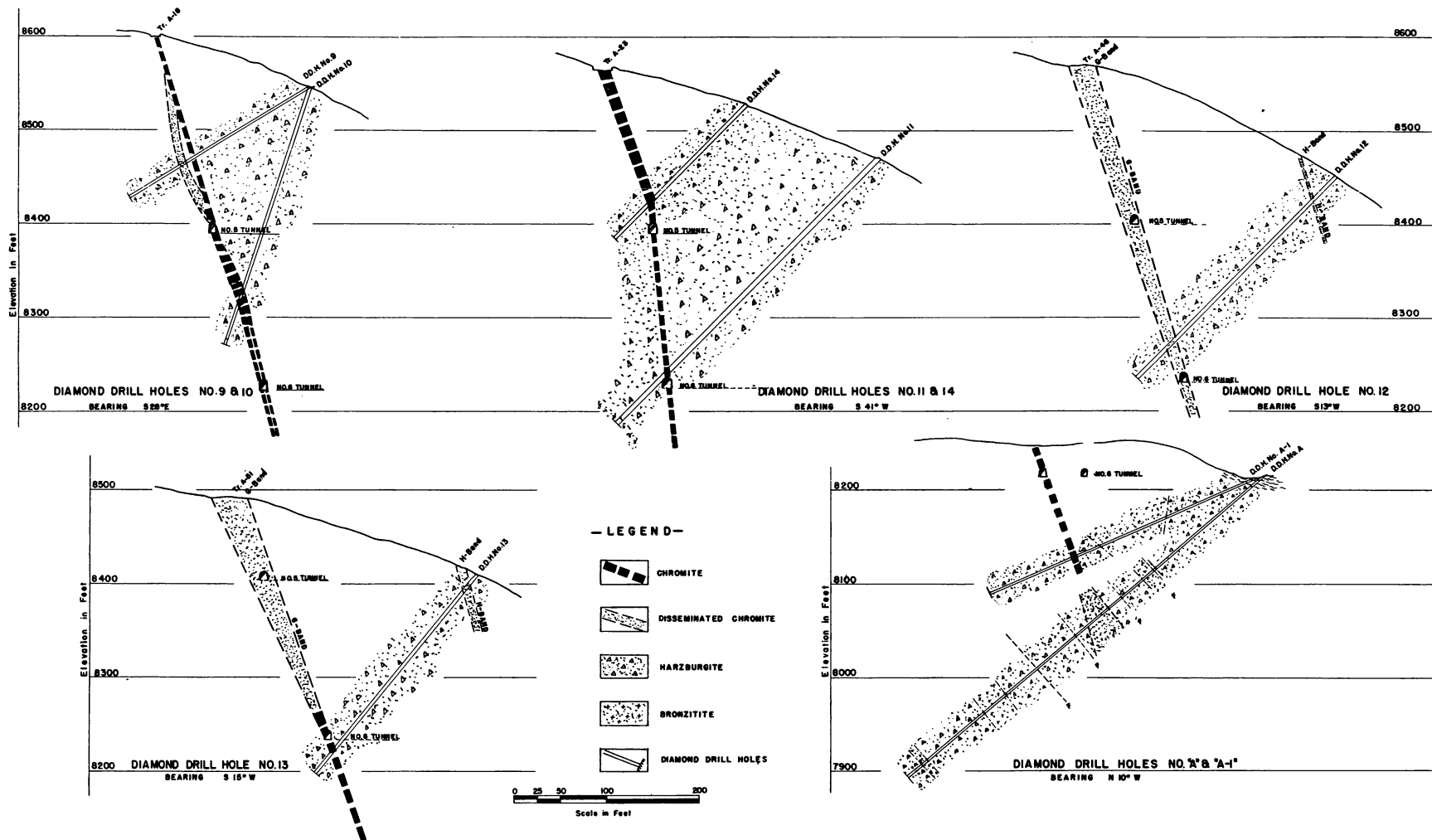


Figure 7. - Diamond-drill-hole sections, Benbow area, Stillwater County, Mont.

to 5 feet thick with sharply defined walls. Elsewhere, layers of chromite-rich and chromite-poor rock alternate over a width of 2 to 25 feet. The contact on the hanging-wall side is generally gradational, but this condition in some places exists also on the footwall side.^{10/}

The chromite bands in the Benbow deposit are more faulted than those at the Mouat and are cut by several large diabase dikes. Furthermore, the silicate minerals in the Benbow ore are more highly serpentinized; and the wall rocks, although generally hard, are more broken and fractured. The serpentine weathers rapidly; consequently much sloughing has occurred in mining, especially in the higher-grade sections. Double drift sets and spiling are required at all dike intersections. These characteristics complicate the sublevel method of stoping as used. Regardless of the stoping method followed, some dilution by waste rock will result.

Work by the Bureau of Mines

Surface trenching by the Bureau of Mines was done at 50-foot intervals for about 8,400 feet along the outcrop. In three places, however, it was not feasible to get through the deep overburden and glacial drift. During this trenching program, 113 trenches were dug and 168 channel samples cut across the chromite exposures. The average widths and assays for the various sections along the strike are shown in figure 5.

The results justified exploration at depth. Accordingly, diamond core drilling was done; 17 holes, with a combined length of 6,883 feet, were drilled. All holes, except hole 480, were drilled from the surface. Hole 480 was drilled from an underground station on the No. 4 level. The location of these drill holes is shown in figure 5 and drill-hole sections are shown in figures 6 and 7. The pertinent data on this drilling are as follows:

Drill-hole data - Benbow mine

Hole no.	Depth drilled, ft.	Inclination of hole	Bearing of hole	Altitude of ore zone, ft.	Chromite encountered	
					Width ft.	Cr ₂ O ₃ , percent
1	492	-45°	S. 33° W.	8,499	5.0	32.13
2	773	-48°	N. 17° E.	-	-	-
3	414	-45°	S. 19° W.	8,703	4.0	34.69
4	298	-42°	S. 25° W.	-	-	-
5	250	-45°	S. 26° W.	8,826	9.0	23.14
9	230	-30°	S. 28° E.	8,464	6.0	22.35
10	289	-71°	S. 28° E.	8,320	4.5	31.35
11	399	-45°	S. 41° E.	-	-	-
12	305	-45°	S. 13° E.	8,282	4.6	28.93
13	274	-51°	S. 15° W.	8,228	5.5	36.00
14	200	-45°	S. 41° E.	8,434	7.0	32.76
480	505	-55°	N. 05° W.	8,465	5.5	26.42
501	524	-30°	S. 23° W.	-	-	-
502	630	-40°	S. 23° W.	-	-	-
A	502	-39°	N. 10° W.	-	-	-
A-1	255	-22°	N. 10° W.	8,305	4.0	21.60
504	543	-40°	-	-	-	-
	6,883					

^{10/} Work cited in footnote 5, p. 9.

Holes 501, 502, and 504, drilled on the Black Rock claim, encountered no chromite. Inasmuch as chromite was later found in this locality by underground development, it is apparent that those holes passed through fault gaps or barren zones.

The Bureau of Mines sampling of underground workings was limited to 34 channel samples taken in the Eclipse adit. All other underground sampling was performed by the Anaconda Copper Mining Co., and its results were made available to the Bureau of Mines.

Bureau of Mines investigations showed the assay width of the chromite to range from 2 to 8 feet and average 4.9 feet, with an average chromic oxide content of 24.5 percent. Dilution by waste or low-grade rock in mining has and will reduce the average chromic oxide content of the ore.

Work by Anaconda Copper Mining Co.

The Anaconda Copper Mining Co., as agent for the Metals Reserve Corporation, began extensive underground development of the Benbow mine in June 1941. This work later was continued by them as agent for the Defense Plant Corporation. A mine plant, an ore-treatment plant, two large camps, and 3-1/2-mile aerial tram were constructed. The Reconstruction Finance Corporation reports that Government expenditures by the Anaconda Copper Mining Co. at the Benbow property, up to the time all operations were suspended and the plants placed on a stand-by basis in June 1943, amounted to \$3,999,740. Of this amount, \$700,975 was expended on mine development alone.

Mining: During 1941, 1942, and 1943 the Anaconda Copper Mining Co. drove 25,260 feet of drifts, crosscuts, and laterals; 11,630 feet of intermediates; 9,502 feet of raises; and 395 feet of shaft. Diamond drilling totaling 2,638 feet also was done.

Approximately 224,700 tons of ore containing 18.4 percent chromic oxide were mined and/or broken during this development and by sublevel stoping. This development, the areas stoped, and other features are shown in plan and longitudinal section in figure 5.

Milling: The Benbow mill was designed to treat 1,000 tons of ore a day by gravity concentration, but only one 500-ton unit was completed. The ore was treated by crushing, grinding, classifying, and tabling. Mill operation was begun March 1, 1942, and continued until June 21, 1943, 427.7 days in all. During this period 186,369 dry tons of ore containing 18.34 percent chromic oxide were treated. The concentrates produced amounted to 72,566 dry tons containing 41.46 percent chromic oxide with a Cr:Fe ratio of 1.61. The mill recovery during the first 3 months in 1942 was 82.17 percent but had reached an average of 90.82 percent for the 6 months in 1943.

The cost of mining, milling, royalties, amortization, and the loading and shipping of concentrates to Columbus, Mont., for the 16 months ended June 30, 1943 are reported as follows:

	Cost per ton	
	Ore	Concentrates
Mining.....	\$7.295	\$18.664
Primary crushing.....	.057	.147
Aerial tram operation...	.229	.587
Concentrating.....	1.632	4.173
Subtotal....	\$9.213	\$23.571
Royalties		1.480
Amortization.....		7.250
Loading and shipping.....		2.938
Total per ton of concentrate.....		\$35.239

During this operation an average of 435 tons of ore was treated for each day operated. The concentration ratio was 2.56. Operations were still in the stage of development and adjustment. The mill operation had not attained its capacity or reached maximum efficiency. Costs could have been reduced materially by a continuing and stabilized operation.

Mouat-Sampson Mine

The Mouat chromite deposits were first located many years ago by the Nye Corp. when that corporation was developing and operating the nearby Mouat copper-nickel property. The Mouat family of Denver, Colo., was interested in both properties and eventually acquired the principal ownership. M. W. Mouat later inherited the Mouat interests and has done some work on the Mouat chromite property during more than 25 years. In 1939, Edward Sampson located two claims adjoining the Mouat group. A compromise boundary is reported to have been agreed upon by Mouat and Sampson.

The Bureau of Mines started trenching the chromite outcrops on this property in October 1939. To better determine the extent and nature of the deposits at depth, the Bureau started a program of diamond core drilling in June 1941.

In the spring of 1942 the Bureau of Mines investigations had proceeded sufficiently to justify an extensive development program, which was undertaken by the Anaconda Copper Mining Co., as agent for the Metals Reserve Corporation, with the procedure and results as reported elsewhere in this report.

The Deposits

The geology at the Mouat-Sampson property conforms to the general pattern of the ultramafic zone of the Stillwater complex. The chromite bands, however, have a general N. 35° E. strike instead of the general northwest strike characteristic of the other deposits in the area. Three mineralized zones occur in the Mouat-Sampson property. The upper and middle zones, referred to respectively as the "H" and "G" bands, are about 300 feet apart, closely parallel each other, and dip 55° to 65° northwest. The third or lowest zone contains only irregular streaks and pods of chromite and some disseminations over an irregular width; it is considered too low-grade to justify extensive exploration at this time.

The "H" band or zone is composed of a massive chromite band 6 inches to 2 feet wide and a band of disseminated chromite 1 to 4 feet wide.

The "G" band is characterized by alternating layers of massive and disseminated chromite. In places it has been exposed for widths as much as 25 feet. The higher-grade ore, however, lies on the foot-wall side, the grade gradually decreasing toward the hanging wall.

The Mouat-Sampson deposits are cut by two major and three minor faults (fig. 8). The Lake fault has cut off the deposits to the northeast of the mine workings (figs. 9 and 10). It strikes N. 72° W. and dips 60 degrees southwest. This fault has not been encountered in the mine workings but was cut by several drill holes. The possible extent of the chromite to the northeast of this fault is not known. The Cliff fault strikes N. 70° to 80° W. and dips 30° - 50° southwest. It offsets the chromite bands about 600 feet at the surface, whereas its displacement at depth is 30 to 40 feet. The Vertical Dike and Little faults are of minor importance; they have caused only small offsets of the chromite bands. In general, faulting at the Mouat-Sampson mine is not considered to be of any material handicap to development or stoping.

Work by the Bureau of Mines

Trenching by the Bureau of Mines along the strike of the chromite bands was begun in October 1939. Except for several recesses due to difficult climatic conditions, this work continued until late in 1942. Trenching was done at intervals within an area beginning about 200 feet southwest of the Lake fault and extending southwesterly for about 3,400 feet into and beyond the Bald Eagle claim. In some sections precipitous slopes, deep rock slides, or heavy overburden either eliminated the need for, or did not permit, trenching. Both the "H" and "G" chromite bands are offset by faulting, particularly by the Cliff fault. In the westward extension, more of the "H" band was exposed than the "G" band because of shallower overburden. A series of small faults was exposed in that vicinity, but the underground workings there indicate that the faults do not extend to any appreciable depth. The location of the trenches and the results of sampling are shown in figures 8, 9, and 10.

Trenching was also done in potential ore-bearing areas eastward from Mountain View Lake and the Stillwater River. Considerable float, with some chromite-bearing boulders weighing as much as several tons, was found, but no chromite was exposed that could definitely be considered as being in place. This area appears to be intensely faulted and fractured.

A 75-foot shaft was sunk on an exposure of chromite east of Mountain View Lake. This shaft definitely intersected the footwall rock (bronzitite) but was mainly in large fragments of ultramafic rocks with some sand. An 18-foot crosscut was driven north from this shaft, 40 feet below the collar. The work indicated that this large block of chromite might not be in place. Drill hole 15 was then drilled vertically, 115 feet north of the shaft, to a depth of 400 feet. It encountered no chromite but did disclose that the ultramafic zone existed to that depth and that, if this is a slide block, it is of great extent and probably contains much chromite.

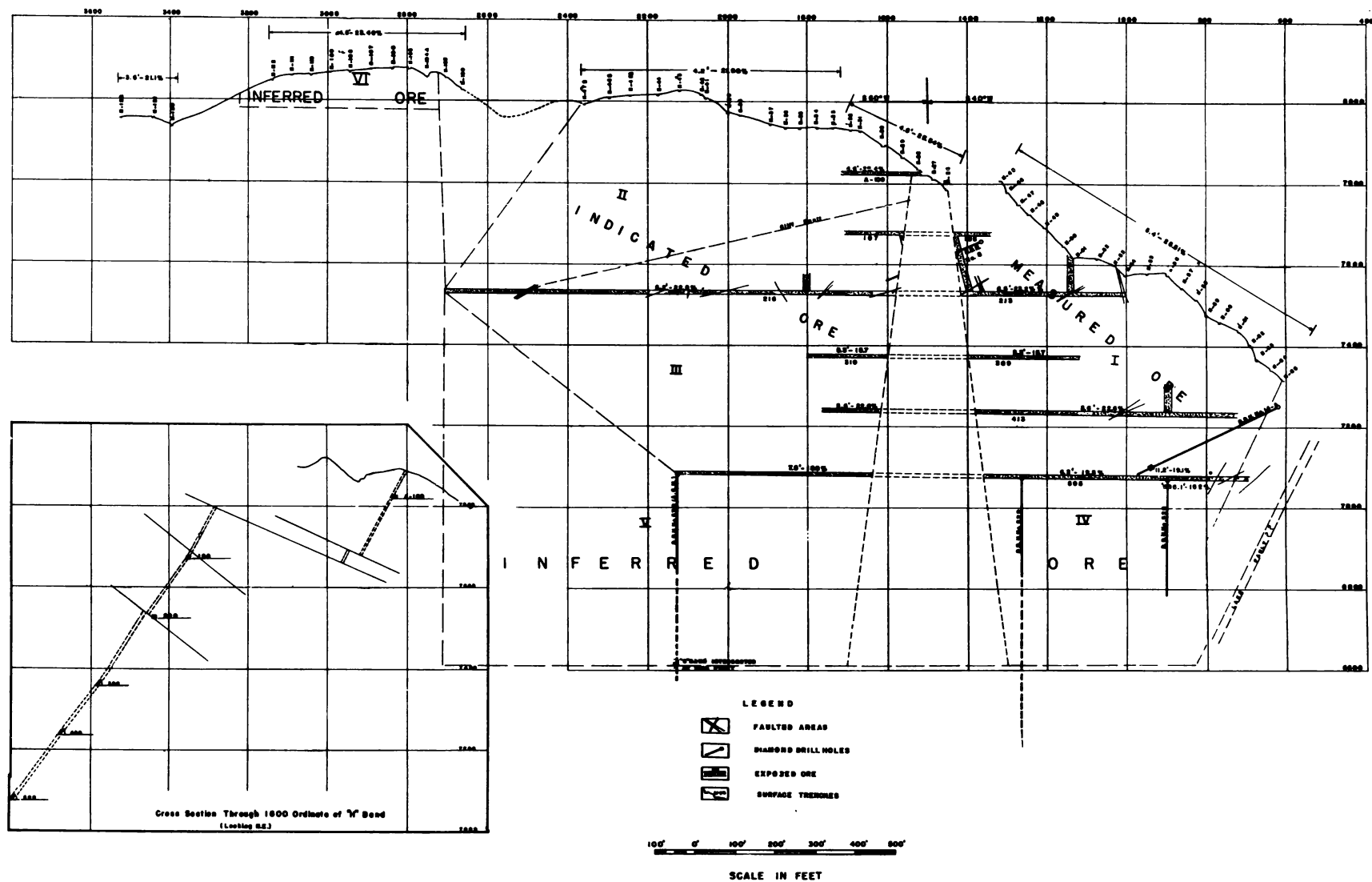


Figure 9. - Longitudinal projection, "H" band, Mouat-Sampson mine.

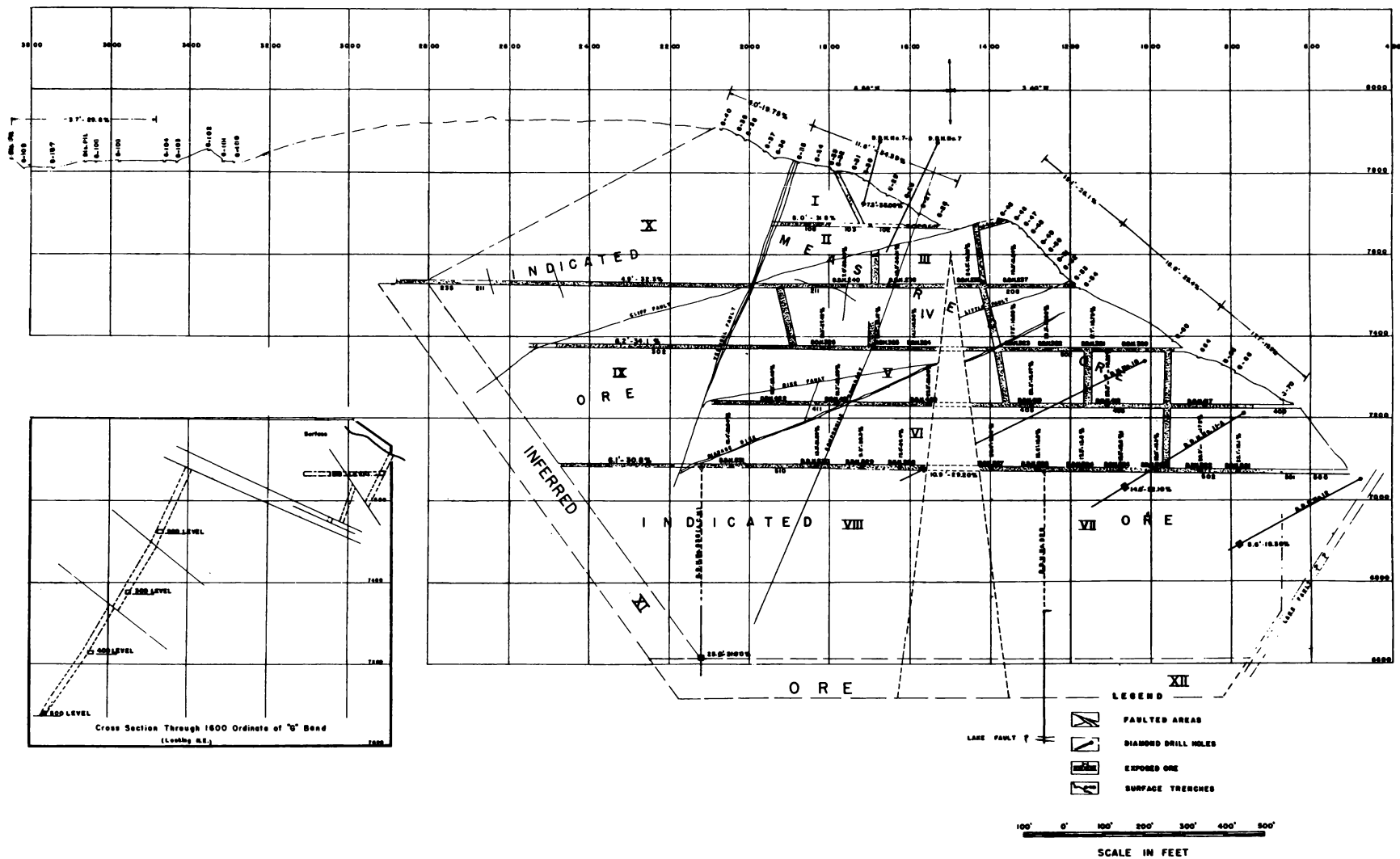


Figure 10. - Longitudinal projection, "G" band, Mouat-Sampson mine.

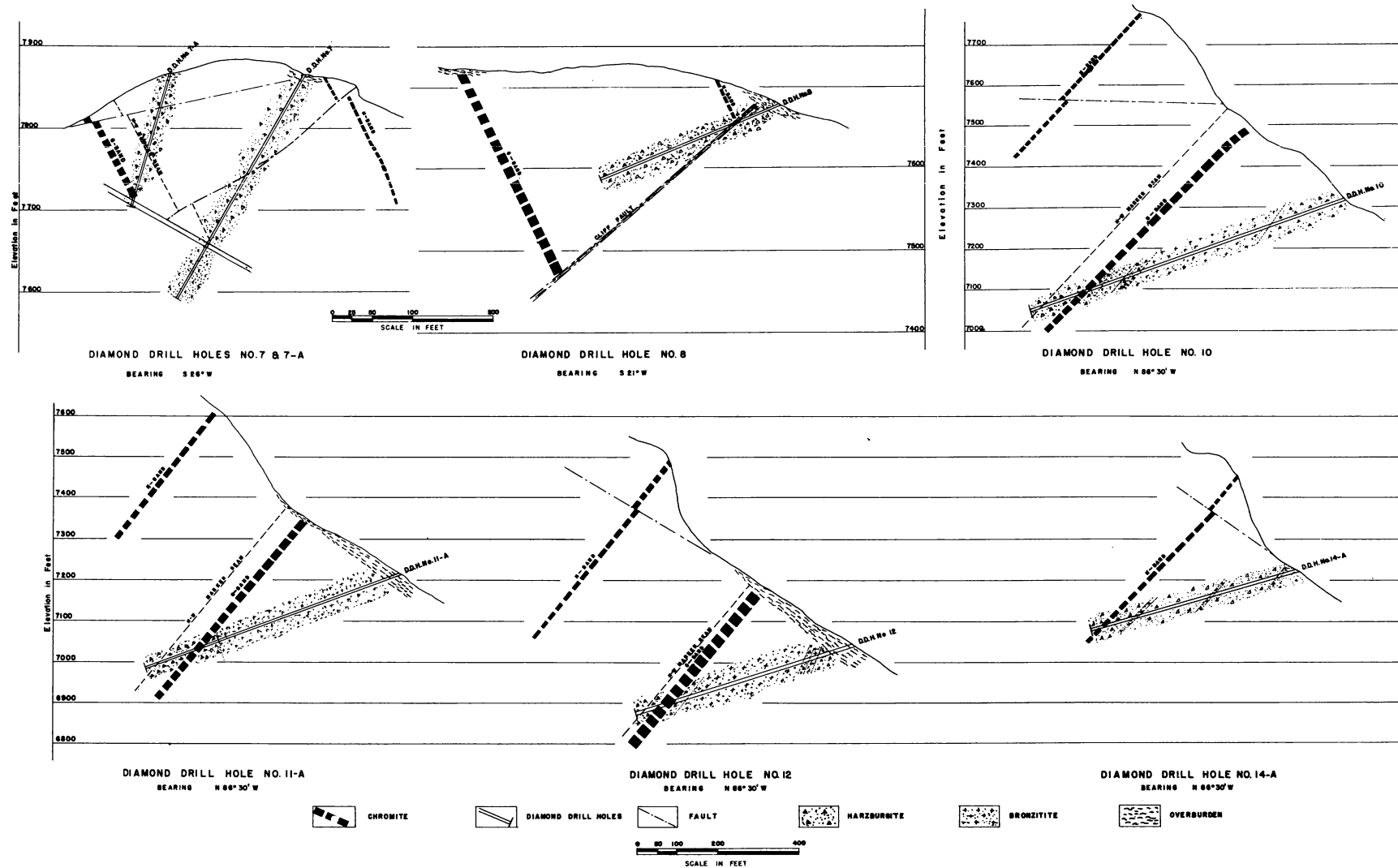


Figure 11. - Diamond-drill-hole sections, Mouat area, Stillwater County, Mont.

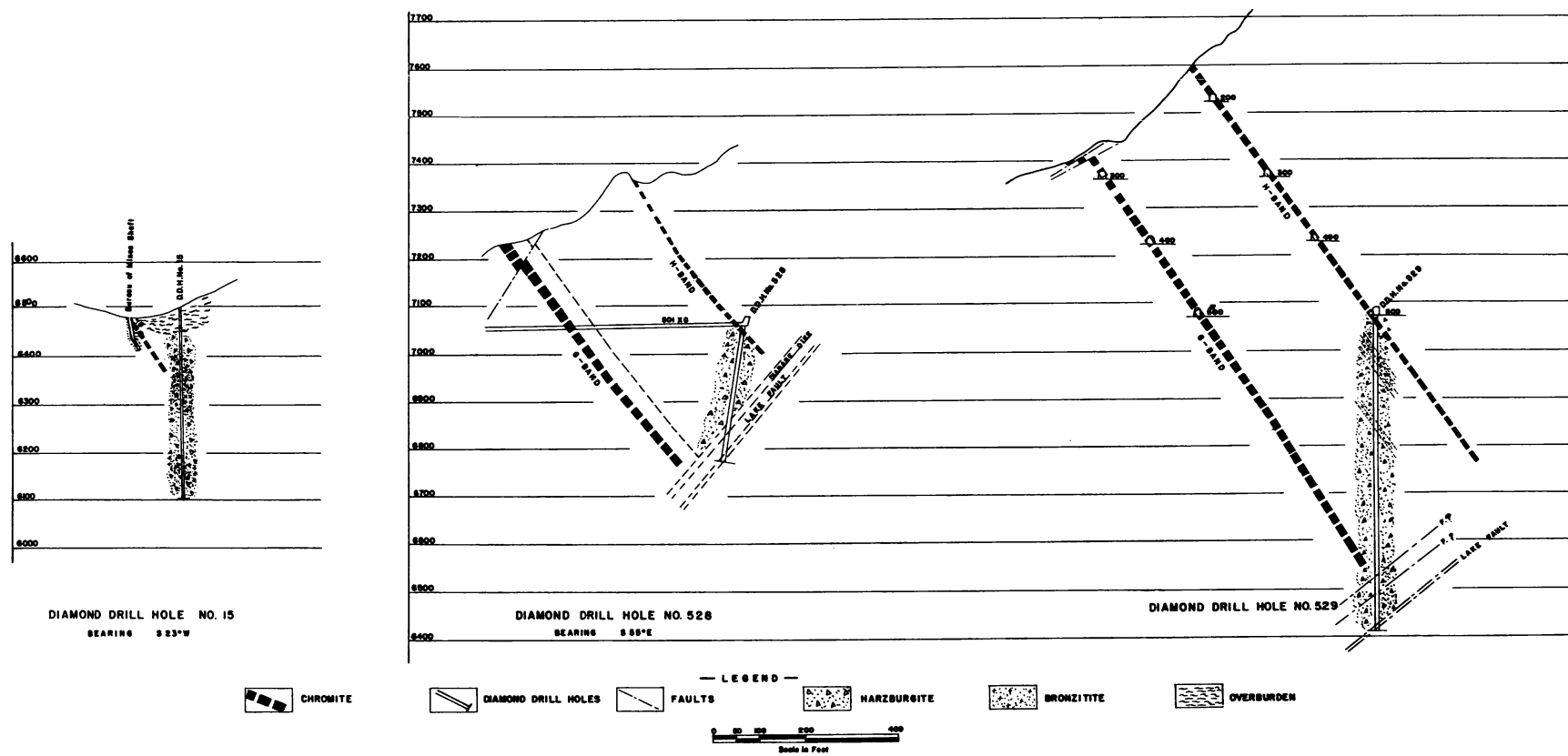


Figure 12. - Diamond-drill-hole sections, Mouat area, Stillwater County, Mont.

Diamond core drilling was begun in June 1941 and continued to March 1943. Ten holes, with a combined length of 4,687 feet, were drilled. Data on this drilling follow:

Drill-hole data - Mouat-Sampson mine

Hole no.	Depth drilled, ft.	Inclination of hole	Bearing of hole	Altitude of ore zone, ft.	Chromite encountered	
					Width, ft.	Cr ₂ O ₃ , percent
7	317	-60°	S. 26° W.	-	-	-
7-A	168.5	-70°30'	S. 26° W.	7,727	6.00	35.06
8-A	240	-22°	S. 21° W.	-	-	-
10	828	-19°	N. 86°30' W.	7,074	8.92	29.20
11-A	681	-20°	N. 86°30' W.	7,035	12.10	22.10
12	571	-18°	N. 86°30' W.	6,890	7.05	18.30
14-A	532	-16°	West	7,100	9.20	19.10
15	400	Vertical	-	-	-	-
528	287.5	-80°	S. 55° E.	-	-	-
529	662	Vertical	-	-	-	-
	4,687					

The locations of these drill holes are shown in figures 8, 9, and 10. Drillhole sections are shown in figures 11 and 12.

Holes 7 and 8-A cut no chromite; apparently they went through fault gaps. Holes 528 and 529 were drilled from the No. 5 level. Neither of these holes encountered chromite but did cut the Lake fault. Hole 535, later drilled by the Anaconda Copper Mining Co. to the west on the same level, did cut the "G" band, however, at an altitude of 6,590 feet, or 460 feet vertically below the No. 5 level. The "G" band at this point was 25 feet wide and assayed 21 percent chromic oxide.

From the results of the work by the Bureau and by the Anaconda Copper Mining Co., the average assay width of the "H" band has been estimated to be 5.8 feet. The average assay grade was estimated to be 22.1 percent chromic oxide. The average width of the "G" band is 16 feet, and its average assay grade is 21.5 percent chromic oxide. The band of massive chromite in the "G" band contains more than 30 percent chromic oxide in widths up to about 8 feet. Some dilution by waste or low-grade rock beyond the average assay widths stated has and will result from mining operations; consequently the grade of ore mined will be reduced by a corresponding amount. On the other hand, it may be found to be more practical and economic to mine a narrower width of the "G" band thereby improving the grade of the ore.

Work by Anaconda Copper Mining Co.

The Anaconda Copper Mining Co., as agent for the Metals Reserve Corporation and later for the Defense Plant Corporation, began its extensive program of development and operation at the Mouat-Sampson mine late in 1941. A large mine plant, an ore-treatment plant, two large camps, and a 1-1/4-mile aerial tram were constructed. The Reconstruction Finance Corporation has reported that \$8,421,298 in Government funds had been expended on this work as of October 1943.

Mining: The underground workings driven by the Anaconda Copper Mining Co. consist of 29,804 linear feet of drifts, crosscuts, and laterals, 335 feet of intermediate workings, and 8,519 feet of raises. The deposits are developed for more than 2,800 feet along the strike and more than 800 feet on the dip. Diamond core drilling also was done to the extent of 3,218 feet. Available reports show that about 183,200 tons of ore containing 21.64 percent chromic oxide were mined and/or broken by this development and by shrinkage stoping. Most of this ore was obtained, however, from development workings. The larger part of the ore broken in the experimental stopes remains in those stopes. This development, the area stoped, and other features are shown in figures 8, 9, and 10.

Milling: The Mouat mill originally was designed for a daily capacity of 2,000 tons of ore. However, only two 500-ton units were completed and operated. The ore was concentrated by classifying and tabling. A flow sheet of the mill as operated is shown in figure 13. This mill was operated from the latter part of April 1943 until October 29, 1943, when it was closed down and placed in a stand-by condition. During that period it operated for 130.4 days, treating 77,696 dry tons of ore containing 19.26 percent chromic oxide and producing 29,538 dry tons of concentrates containing 38.81 percent chromic oxide with a Cr:Fe ratio of 1.44. The average recovery is reported to have been 76.62 percent but for the last 4 months of its operation, recovery reached 86 percent. This mill was, however, never operated at full capacity or maximum efficiency.

Production costs for a 4-month period ended October 31, 1943, are reported as follows:

	Cost per ton	
	Ore	Concentrates
Mining	\$6.815	\$18.526
Primary crushing .....	.095	.257
Aerial tram operation .....	.211	.573
Concentrating	2.798	7.462
Subtotal	\$9.919	\$26.818
Royalty (3.57¢ a unit)		1.404
Advance lease payment .....		.447
Amortization		7.250
Loading and shipping to Columbus, Mont.		2.938
Total per ton concentrate		\$38.857

During the above 4-month period, an average of 600 tons of ore a day was milled; the concentration ratio was 2.67. The charge for advance lease payment, the high charge for amortization, and the charge for loading and trucking concentrates to Columbus, Mont., are of special note. Production costs could be greatly reduced, probably by 50 percent or more, by a stabilized and continuing operation under more normal conditions.

Gish Mine

The Gish property, known also as the Boulder River property, is near the western end of the Stillwater complex. The claims were located first in 1918,

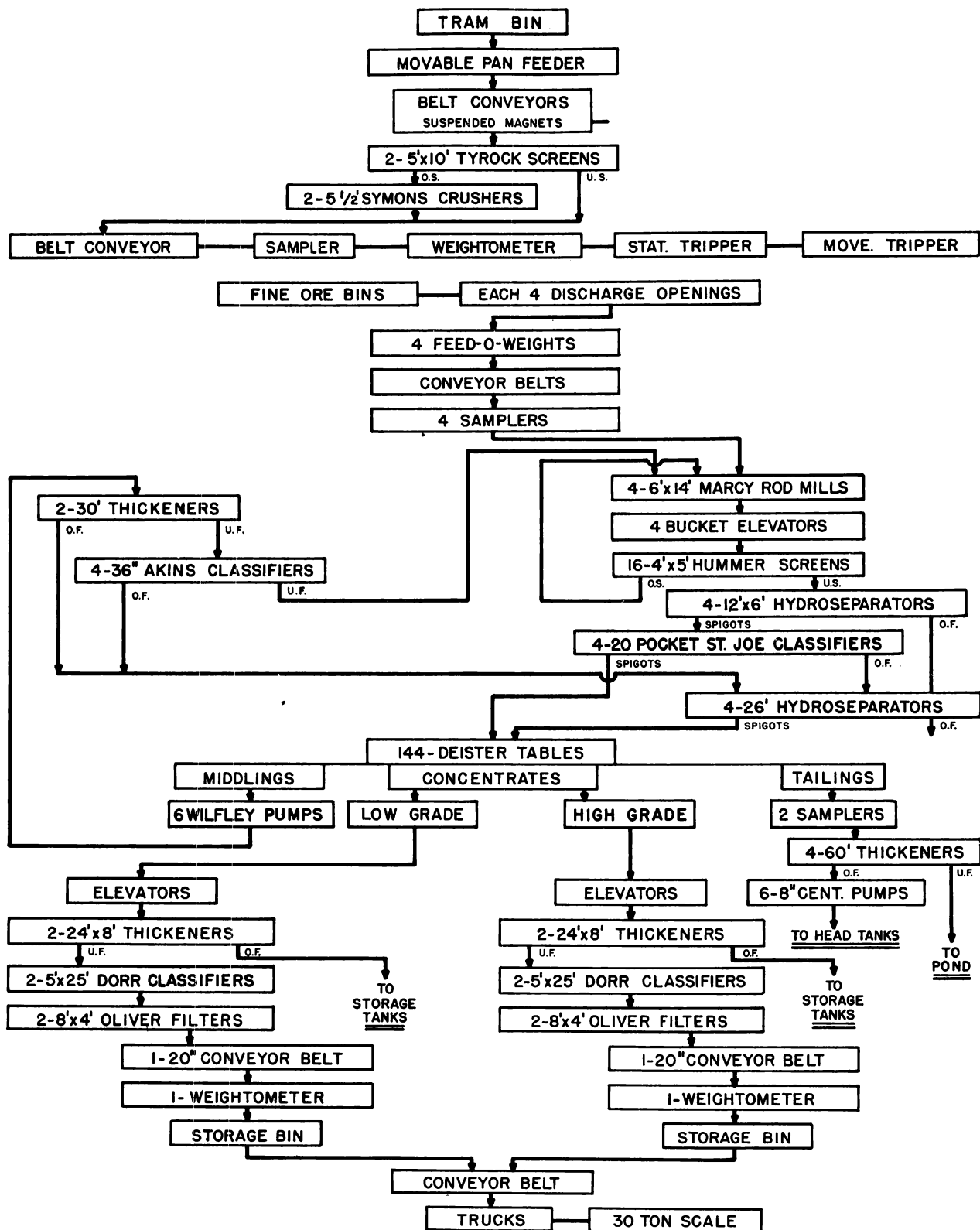


Figure 13. - Mouat-mill flow sheet.

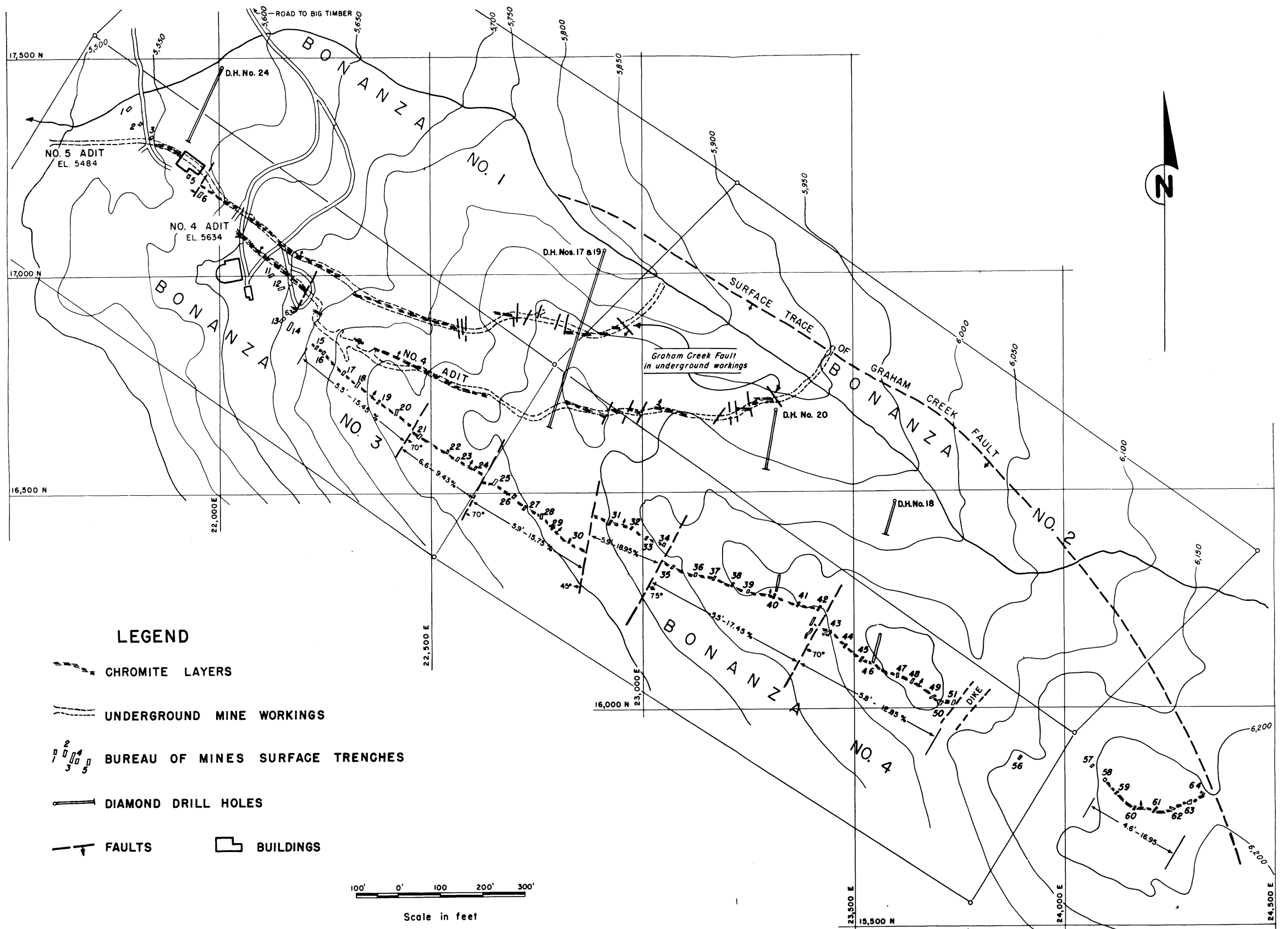


Figure 14. - Surface and underground plan, Gish mine, Sweetgrass County, Mont.

at which time the U. S. Chrome Corp. attempted to mine the deposit. Two adits were started, and a small gravity-concentration mill was constructed. This work ceased, however, at the close of the World War of 1914-18. Nothing further was done at the property until the Bureau of Mines started its trenching and drilling program in September 1941. The Anaconda Copper Mining Co., as agent for the Metals Reserve Corporation, began its exploration of the Gish property in the spring of 1942. The property was purchased in May 1945 by Ralph G. Taylor of Billings, Mont., but he has no plans for mining it.

The Deposits

The geology at the Gish property is, in general, similar to that at the Benbow and Mouat-Sampson properties. The chromite bands strike N. 60° W. and dip 65° northeast at the western end of the claims; at the eastern end of the claims they strike N. 80° W. and dip 40° northeast. With the exception of a few minor gaps, they have been traced along their general strike for more than 3,000 feet. A major northwest-trending fault, known as the Graham Creek fault, which dips about 20° southwest, has cut off the chromite at depth and at the eastern end. Numerous small northeast-trending faults, dipping at various angles up to 75°, some to the southeast, others to the southwest, have caused some offsets but these generally are of small displacement.

Work by the Bureau of Mines

During September and October 1941 the Bureau of Mines dug 61 trenches at intervals along the strike of the chromite band. The total combined length of these trenches was 789 feet. One hundred eighty-six channel samples, representing 500 linear feet, were taken. The location of the trenches is shown in figure 14. Trench sampling data are given in the following table:

Trench sampling data - Gish mine

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
1-1.....	1.6	20.60	17-1.....	4.0	24.33
2.....	4.5	1.57	2.....	2.4	7.32
3.....	4.5	6.22			
10-1.....	2.4	24.90	18-1.....	2.6	22.68
2.....	3.5	9.95	2.....	4.8	8.60
15-1.....	0.7	34.47	19-1.....	1.3	34.55
2.....	2.1	17.97	2.....	2.0	5.74
3.....	2.2	5.88	3.....	1.7	16.10
16-1.....	0.8	30.01	20-1.....	1.7	16.42
2.....	2.5	24.72			
3.....	4.4	5.58			

Trench sampling data - Gish mine (Continued)

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
21-1.....	0.5	17.98	33-1.....	1.8	38.26
2.....	1.2	4.24	2.....	3.5	11.96
22-1.....	1.3	36.06	34-1.....	1.6	40.79
2.....	4.2	2.77	2.....	3.2	12.44
3.....	3.0	3.68	35-1.....	1.7	32.08
23-1.....	2.5	26.07	2.....	4.6	8.66
2.....	4.3	4.94	36-1.....	1.7	37.93
3.....	3.9	5.32	2.....	1.2	3.58
24-1.....	1.5	29.77	3.....	3.2	20.93
2.....	4.3	8.42	37-1.....	2.0	37.74
25-1.....	1.4	36.01	2.....	1.3	3.77
2.....	1.3	5.30	3.....	1.9	15.38
	2.4	13.00	38-1.....	1.5	34.15
26-1.....	1.6	35.26	2.....	1.2	1.77
2.....	1.2	11.88	3.....	1.9	6.27
3.....	2.0	14.41	39-1.....	2.4	36.72
27-1.....	1.5	40.77	2.....	1.4	8.20
2.....	1.3	4.75	3.....	1.9	12.38
3.....	1.4	17.17	40-1.....	1.0	37.84
28-1.....	1.0	29.39	2.....	5.2	13.13
2.....	1.6	6.18	41-1.....	1.4	31.51
3.....	4.7	9.52	2.....	.9	3.77
29-1.....	1.5	35.65	3.....	3.5	12.14
2.....	2.1	2.88	42-1.....	.7	28.54
3.....	1.9	9.84	2.....	3.7	6.97
30-1.....	2.2	37.04	43-1.....	1.3	9.59
2.....	3.0	4.34	2.....	2.0	1.75
3.....	3.3	7.16	3.....	1.2	5.27
31-1.....	2.9	30.25	44-1.....	1.3	32.25
2.....	4.3	1.88	2.....	3.0	9.48
3.....	1.4	18.50	45-1.....	1.9	31.12
32-1.....	2.8	33.46	2.....	1.5	2.82
2.....	1.2	7.50	3.....	2.6	11.97
3.....	1.2	15.48			

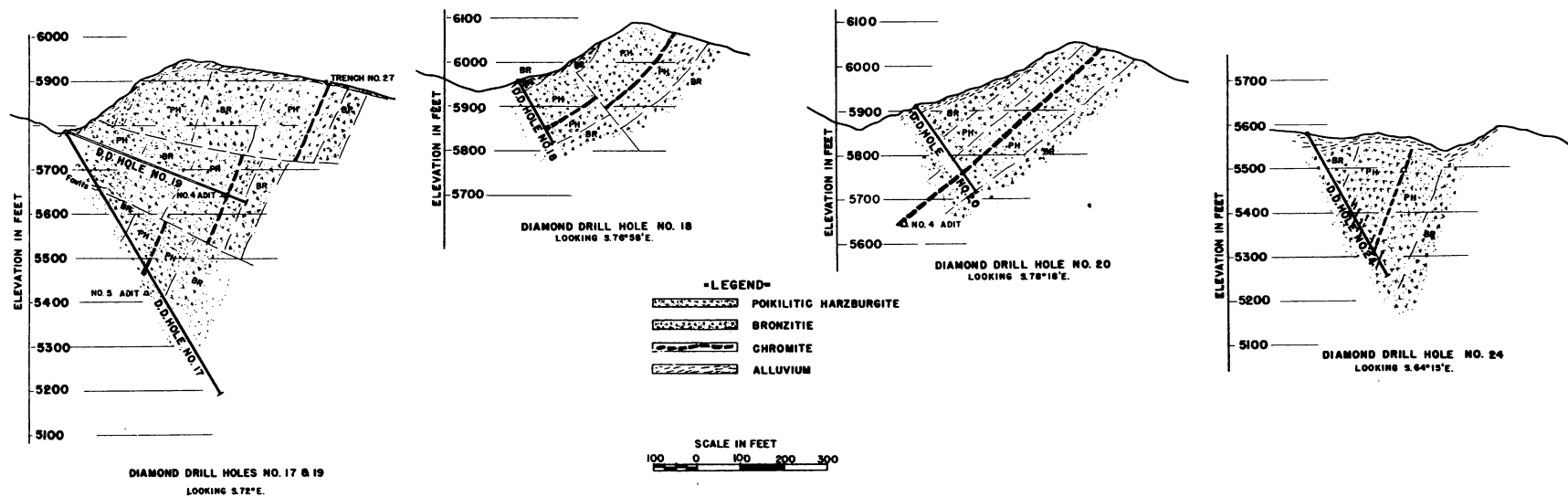


Figure 15. - Diamond-drill-hole sections, Gish claims, Sweetgrass County, Mont.

Trench sampling data - Gish mine (Continued)

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
46-1.....	2.0	36.09	58-1.....	1.1	30.39
2.....	3.4	2.50	2.....	.5	4.51
3.....	2.1	16.61	3.....	.8	7.64
47-1.....	.8	34.67	59-1.....	1.1	40.75
2.....	1.4	5.45	2.....	4.9	11.30
3.....	2.1	9.73	60-1.....	1.5	42.91
48-1.....	1.9	39.33	2.....	1.7	10.26
2.....	2.6	4.15	61-1.....	1.5	42.08
3.....	2.0	18.71	2.....	4.5	4.81
49-1.....	.9	27.62	3.....	4.6	10.57
2.....	4.3	1.45	62-1.....	.9	39.35
3.....	3.0	7.98	2.....	1.6	11.90
50-1.....	1.2	38.71	63-1.....	1.6	29.15
2.....	1.0	.68	2.....	.9	4.60
3.....	1.5	16.06	3.....	1.3	13.99
51-1.....	1.0	33.95	64-1.....	1.1	40.24
2.....	2.5	1.98	2.....	1.5	.63
3.....	2.5	.78	3.....	1.4	17.30
4.....	1.5	16.53			

The average assay width of the chromite band as sampled in the trenches is 5.37 feet; the average chromic oxide content is 15.1 percent.

Diamond core drilling was begun in March 1942. Five holes, with a combined length of 1,924 feet, were drilled to cut the chromite band at depths of 125 to 500 feet below the surface. A sixth hole, 20-A, was abandoned at a depth of 11 feet. These drill holes were distributed over a strike distance of 1,900 feet. The maximum vertical range between the collar of the highest drill hole and the lowest point at which the chromite band was cut by a drill hole is 900 feet.

The location of the drill holes is shown in figure 14. Drill-hole sections are shown in figure 15. Drill-hole data and the width and assay of the chromite cut are as follows:

Drill-hole data - Gish mine

Hole no.	Depth drilled, ft.	Inclination of hole	Bearing of hole	Altitude of ore zone, ft.	Chromite encountered	
					Width, ft.	Cr ₂ O ₃ , percent
17	700	-58°	S. 18° W.	5,475	6.7	16.07
18	159	-60°	S. 13° 58' W.	5,840	5.0	20.00
19	455	-20°	S. 18° W.	5,640	5.3	21.7
20	239	-54°	S. 11° 42' W.	5,760	4.0	12.3
20-A	11	-54°	S. 3° 18' E.	-	-	-
24	371	-60°	S. 25° 48' W.	5,304	1.4	16.4
	1,935					

The average width of chromite cut in the drill holes is 4.3 feet; its average content of chromic oxide is 17.8 percent.

The combined weighted average of all surface, drill-hole, and underground samples indicates an average width of 4.8 feet and an average chromic oxide content of 16.3 percent.

Work by Anaconda Copper Mining Co.

The Anaconda Copper Mining Co., as agent for the Metals Reserve Corporation, began to explore the Gish deposits early in the spring of 1942. A camp and several mine-plant buildings were erected and equipped. Two adits, Nos. 4 and 5, were driven on a general easterly, but rather irregular, course, mostly following the trend of the chromite layers, for 1,600 and 2,200 feet, respectively (fig. 14). About 600 feet of crosscuts and 265 feet of raises also were driven.

The chromite layers, as exposed along these adits, are offset by numerous small northerly trending faults of small displacement. These small faults are especially numerous within a distance of about 400 to 600 feet westerly from a major fault. This relatively flat, southwest-dipping, major fault apparently is the Graham Creek fault. On meeting it, both adits were turned sharply northward and continued several hundred feet in barren ground. Two core-drill holes, with a combined length of 770 feet, were drilled by the Anaconda Copper Mining Co. in an attempt to locate the chromite on the northwest or footwall side of this fault. The second hole cut several small stringers of chromite, but the main chromite band was not found.

This work was concluded early in 1943, for by that time the chromite situation had improved considerably because of an increase in chromite imports, and an acute labor shortage had developed. Some ore was mined during this development, but none of it was milled.

Nye Basin Area

The Nye Basin area lies between the Benbow and Mouat properties and is accessible from those properties by Forest Service trails. Claims were first located in the Nye Basin many years ago; but since that time many locations, some of which conflict, are claimed by various interests. (See Property and Ownership, p. 8.)

Chromite occurs in three areas in Nye Basin. These areas have been designated as the Big Seven fault or upper basin, the Alice Lode or middle basin, and the Lip or lower basin. Other than a short adit on the Alice Lode there are no underground workings. A few shallow test pits or cuts had been dug on some of the claims by the locaters, but most of them were caved. The Bureau of Mines did some trenching and diamond drilling in these areas during 1941.

The Deposits

The ultramafic zone in the Nye Basin is narrower than at Benbow and Mouat. The chromite bands also are narrower and not as extensive. The geology otherwise conforms closely to that at the Benbow. The chromite bands have the same general strike as the Benbow bands, and, except at the Alice Lode, dip to the northeast.

No chromite has been found in place between the exposures in the Big Seven Fault area and the exposures at the Alice Lode - a distance of about 1 mile on the general strike; chromite has not been found between the Alice Lode and the Lip area, a distance of about one-half mile. This is in part due to deep overburden.

Faulting in general has caused small offsets; but, with the exception of the Big Seven fault, little is known of their positions, attitudes and effects. The Big Seven fault trends north and, west of the West Benbow, has cut off the chrome layers. The Bureau of Mines search for the faulted section west of the Big Seven fault proved that it had been displaced about 1,000 feet to the north.

The chrome layers west of the Big Seven fault are similar in character, size, and grade to those on the east side at the West Benbow mine. They have been exposed by trenching throughout a distance of 190 feet; apparently they continue much farther. Deep overburden at the west end made additional trenching impractical. The surface exposures as sampled showed an average width of 6 feet with an average assay grade of 26.0 percent chromic oxide.

At the Alice lode, the chromite has been traced along the strike for about 1,000 feet. Here the chromite dips south. This deviation in dip is due either to a large major fault movement or to surface creep; the latter is more generally indicated. The deposit consists generally of two bands of massive chromite 6 inches to 1 foot wide separated by 3 to 10 feet of waste rock or low-grade disseminated chromite. As trenched along the surface, the average assay width of the chromite layer was 2.92 feet, with an assay grade of 19.6 percent chromic oxide. The Lip of Nye Basin overlooks the Stillwater River. The south half of the Lip is well-exposed. The chromite bands as exposed there are narrow and low-grade, consisting of about a 2-inch width of massive chromite and 2 to 3 feet of disseminated chromite. All are badly faulted. The north half of the Lip is covered by a large alluvial fan, too deep to be explored by trenching.

Work by the Bureau of Mines

Trenching at the West Benbow had traced the chromite band westerly to the Big Seven Fault, but at that time this band could not be found west of the fault. The Bureau of Mines and the Federal Geological Survey jointly studied the Big Seven Fault area with a view of picking up the faulted segment. Magnetic and electrical geophysical surveys were then made by Hans Lundberg, Inc., under contract with the Bureau of Mines. The results of these surveys showed that the chromite bands gave no specific indications by either method. Faults could, however, be recorded where serpentinization had occurred along them but that information was of little value. After the geophysical surveys failed measurements and calculations limited the search to a comparatively narrow zone.

Trenching was then done by the Bureau. The offset segment was found in the third trench dug. After tracing for 190 feet westerly by trenching, two diamond drill holes were put down. Hole 25 cut the chromite band 100 feet below the surface, where it was 4.5 feet wide and assayed 26.0 percent chromic oxide. Hole 26 was planned to intersect the chromite about 200 feet lower in altitude to the north of hole 25. The hole was abandoned, because of badly caving ground.

At the Alice lode, 20 trenches were dug at intervals, and all chromite exposures were sampled. This trenching showed the chromite occurrence to be practically continuous for about 1,000 feet. Hole 21 was drilled 294.5 feet through badly broken ground and encountered no chromite.

No trenching was done in the Lip area for reasons already mentioned. Hole 23 was drilled to explore under the deep alluvial fan at the north end of the area. Several chromite stringers were cut in hole 23, but the chromite band was less than 3 feet wide, with less than 5.0 percent chromic oxide. This hole was stopped at 341 feet after it had penetrated 150 feet into the bronzitite.

The location of the trenches and diamond core drill holes is shown in figure 16. Drill hole sections are shown in figure 17. The trenching and diamond drilling results in the Nye Basin are given in the following tables:

Trench-sampling data - Nye Basin areaBig Seven Fault area

Trench No.	Width sampled, ft.	Assay Cr_2O_3 , percent
10	4.0	29.44
11	8.0	34.03
12	7.3	19.28
13	5.0	21.58

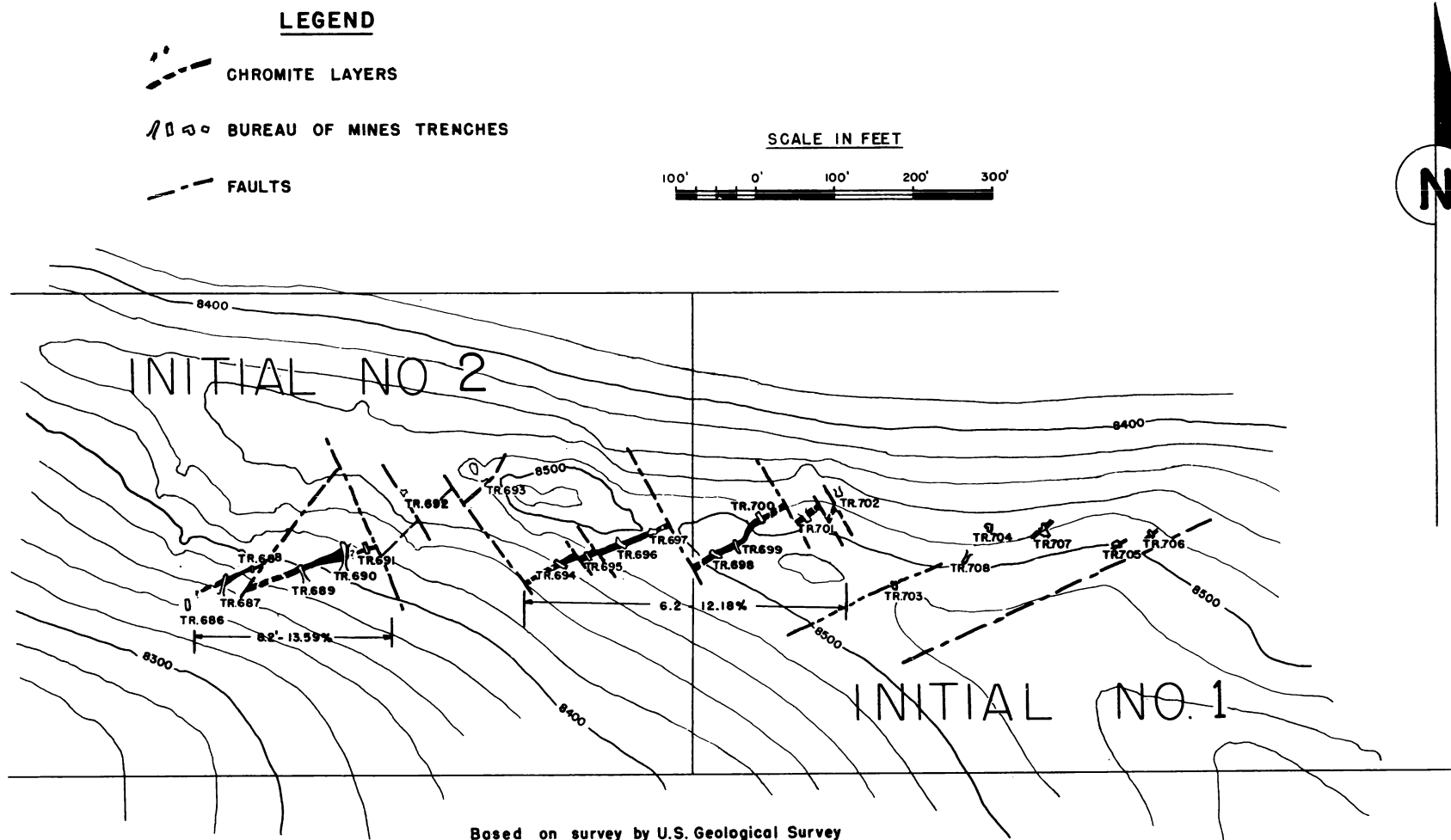


Figure 16. - Nye Basin chromite deposits, Stillwater County, Mont.

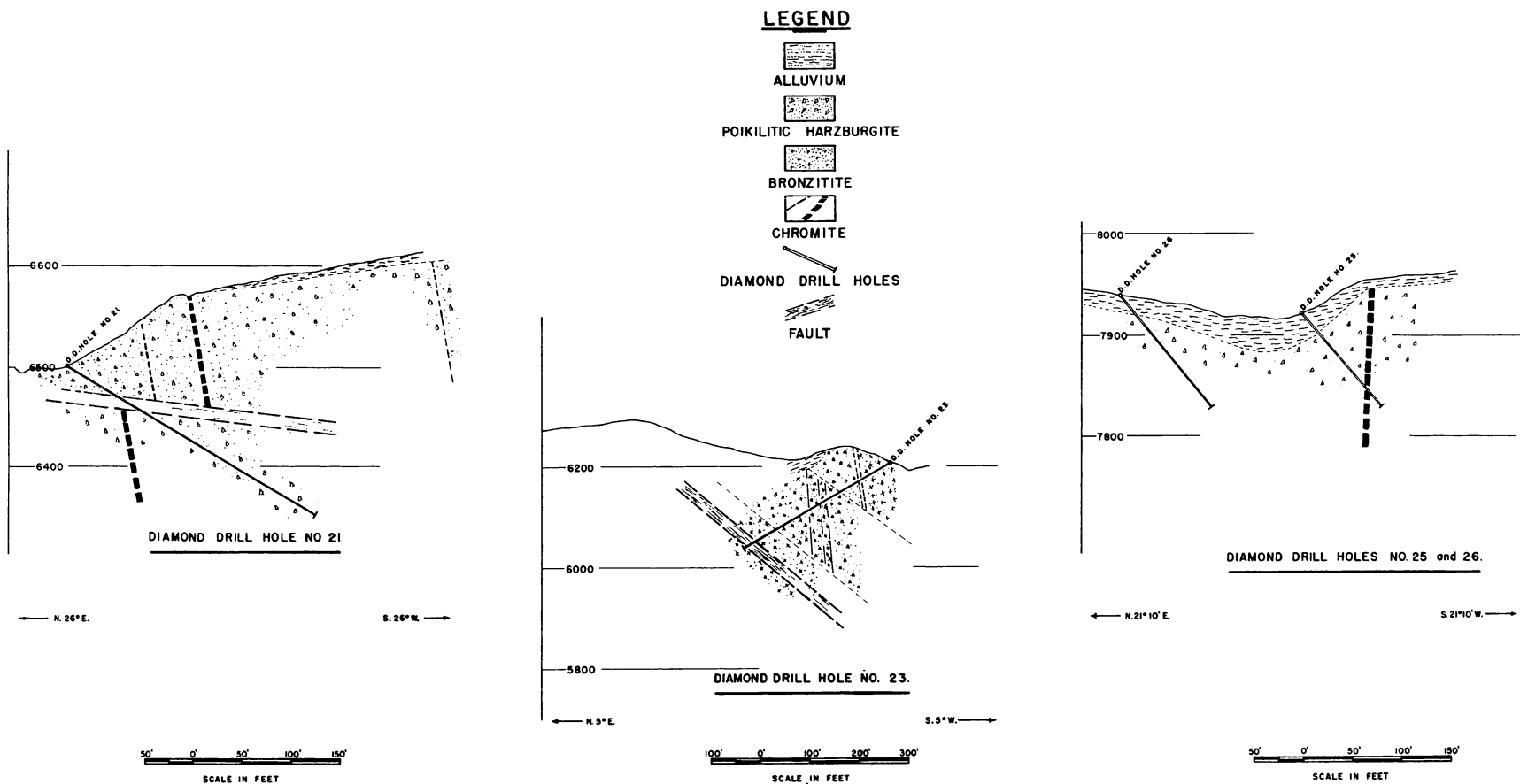


Figure 17. - Diamond-drill-hole sections, Nye Basin area, Stillwater County, Mont.

Trench-sampling data - Nye Basin area (Continued)Alice lode

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	sampled, ft.	Assay Cr ₂ O ₃ , percent
50-1	0.1	21.51	59-1	1.5	8.60
2	.9	38.19	2	1.0	29.37
			3	1.5	5.57
51-1	.8	34.58	4	1.5	19.63
			5	1.0	36.80
52-1	1.3	28.30			
2	2.0	2.85	61-1	1.5	1.83
3	.8	15.28	2	1.0	29.37
4	1.5	38.58			
5	4.0	2.59	60-A-1	.5	31.00
6	.7	35.43			
			64-1	.5	22.55
53-1	1.0	4.29	2	.8	30.88
2	1.1	37.24			
			65-1	1.7	23.18
54-1	1.0	21.84	2	2.5	5.19
2	.9	39.44	3	1.7	16.40
			4	1.0	37.70
55-1	.9	22.76			
			66-1	1.25	30.89
56-1	1.5	22.62	2	3.0	7.94
2	.25	39.07	3	1.25	35.05
58-1	2.0	8.37	Waldo adit-1	1.0	12.70
2	.6	31.92	2	1.0	19.00
			3	1.0	39.50

Drill-hole data - Nye Basin area

Hole No.	Depth drilled, ft.	Inclination of hole	Bearing of hole	Altitude of ore zone, ft.	Chromite encountered	
					Width, ft.	Cr ₂ O ₃ , percent
21	294.5	-30°	South	-		
23	341	-30°	N. 5° E.	-		
25	123	-48°	S. 31°10' W.	7,848	4.5	26.0
26	143.5	-50°	S. 21°10' W.	Abandoned because of caving ground		-
	902.0					

Initial Area

The chromite deposits on the Initial claims are about 1-1/2 miles westerly from the most western chromite exposures on the Mouat property. The area is of

high relief. The altitude at the deposits investigated ranges from 8,300 to 8,400 feet. The Initial claims are accessible from the Mouat mine by 3 miles of Forest Service road over Horseman Flats, then by steep trail, which, after crossing a divide between the Stillwater River and its West Fork tributary at an altitude of 8,700 feet, descends to the property on the west slope. The claims were located August 23, 1941. The only work done on the property before that done by the Bureau of Mines consisted of a few shallow cuts.

The Deposits

The geology of the Initial area is, in general, similar to that at the Mouat mine, although only one chromite band has been found. This band strikes southwest, as do the "H" and "G" bands at the Mouat, but dips steeply both the south and north, a condition due probably to faulting. Many faults, generally with a N. 30 W. strike, cut the formation. Those noted have displaced the chromite band horizontally from 1 to 100 feet.

The chromite band, as exposed in the trenches, is composed of massive chromite up to 1 foot in width on the hanging-wall side, and of disseminated chromite throughout the rest of the band. In some places, however, the disseminations grade into a nearly massive chromite on the foot-wall side. Elsewhere, narrow, short stringers of massive chromite often occur in the center of the band.

Work by the Bureau of Mines

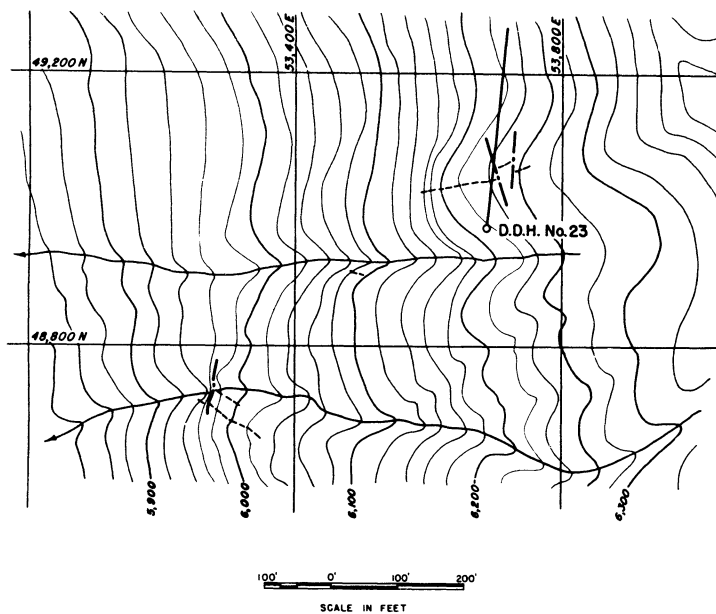
In August 1942, 16 trenches, with a total length of 180 feet, were dug on the Initial Nos. 1 and 2 claims, and 45 channel samples were taken.

The chromite band as exposed in the western trenches on claim No. 2 (fig. 18) has been offset by faults near trenches 688 and 691. West of trench 687 the overburden becomes deep; consequently, the chromite band was not found in trench 686. Attempts to find the chromite between trenches 691 and 694 failed because of wide displacement by faults and also because of deep overburden. Although it was repeatedly offset by faulting, the chromite band was found to be continuous between trenches 694 and 697, and 698 and 700. Other than some narrow stringers of massive chromite exposed in trenches 707, 705, and 706, no chromite was found east of trench 702.

This trenching exposed three main segments of the faulted chromite band, 140, 150, and 200 feet long, respectively. The average assay width of these segments is 6.8 feet; the average content of chromic oxide is 13.2 percent.




No diamond drilling was attempted because of the faulted conditions, the narrowness of the higher-grade chromite and the average low chromic oxide content of the band.

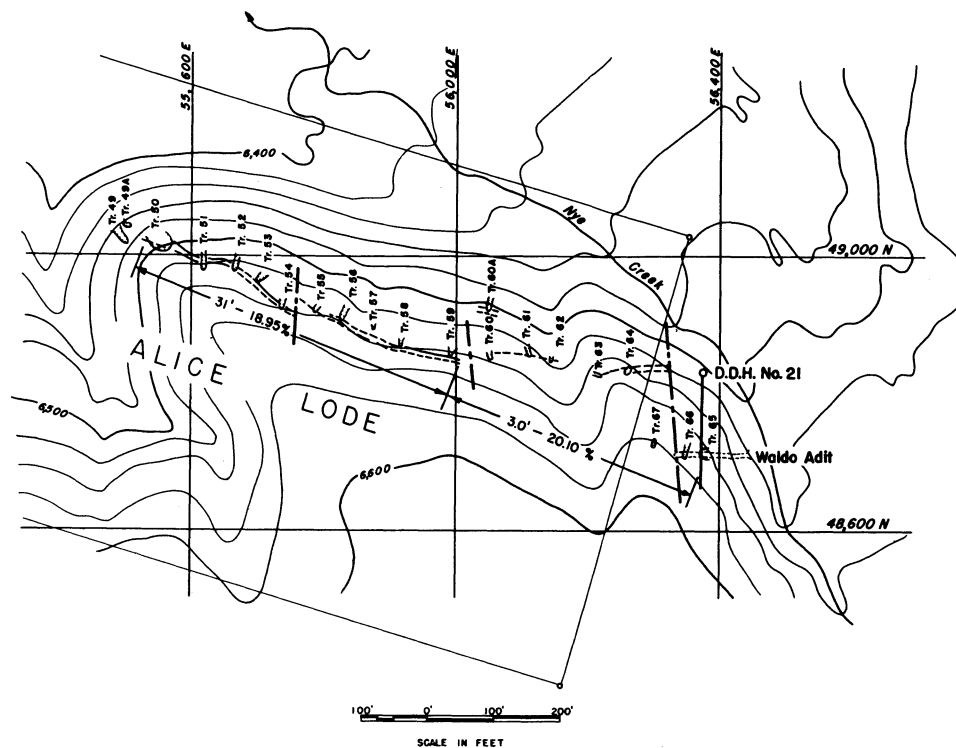
The location and extent of the trenching are shown in figure 18. The trench-sampling results are as follows:



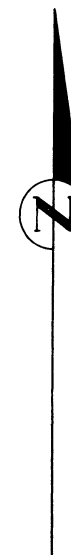
LIP OF NYE BASIN AREA

LEGEND

-  Chromite exposures or indicated continuity
-  Faults
-  Bureau of Mines trenches



ALICE LODE AREA



BIG SEVEN FAULT AREA

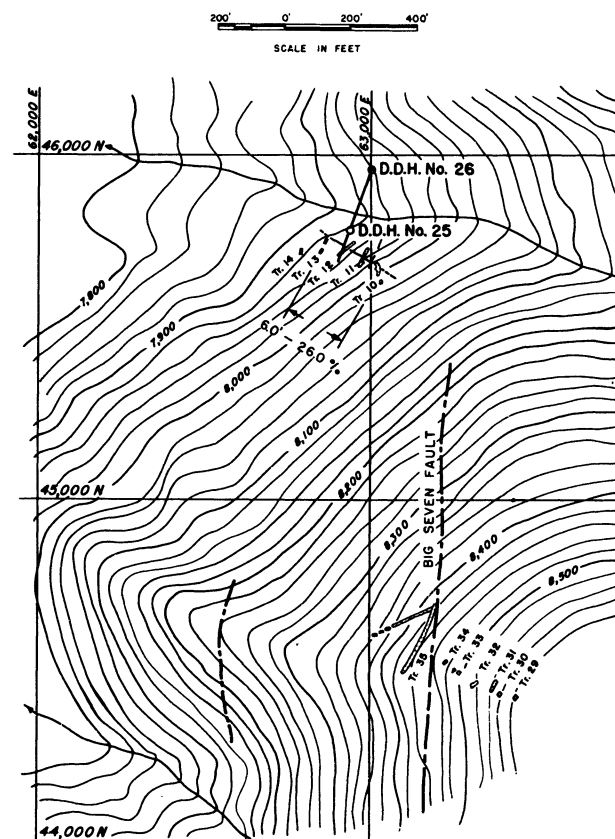


Figure 18. - Initial chromite deposits, Sweetgrass County, Mont.

Trench-sampling data - Initial area

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
687-1	5.3	6.81	696-1	2.0	10.91
2	1.7	15.44	2	4.0	1.69
			3	.9	28.44
688-1	3.5	11.74	4	2.0	2.12
2	3.4	4.57			
3	1.8	22.60	697-1	3.0	30.00
689-1	2.0	2.11	698-1	6.7	9.59
2	.7	29.90	2	.6	33.46
3	5.0	34.29	3	2.1	1.76
4	5.5	9.38			
690-1	1.9	9.94	699-1	6.5	7.53
2	3.0	20.41	2	.5	35.58
3	5.7	.69	3	2.1	2.03
4	.7	25.69			
5	2.0	1.79	700-1	5.0	13.17
691-1	9.0	6.93	701-1	4.8	12.43
2	.4	30.38	2	3.8	.66
3	2.0	2.43	3	.9	30.98
			4	1.8	2.44
694-1	4.1	12.69	702-1	4.5	10.87
2	.7	29.29	2	.9	.89
			3	.5	34.49
695-1	5.8	12.42	4	2.0	2.62
2	.5	34.39			
3	1.0	2.71	705-1	5.4	13.23
			2	.6	40.58
			707-1 ....	.9	42.04

Bluebird Area

The Bluebird claims are about one-half mile west of the Initial claims, on the west side of Cathedral Creek, a tributary of the West Fork of the Stillwater River. The chromite deposits are along the north, east, and west slopes of Bluebird Peak, which attains an altitude of 8,283 feet. Access to the area from the Mouat mine is partly by Forest Service road, thence by steep trails via the Initial claims, or by steep Forest Service trail from the West Stillwater road. The Bluebird claims were located in 1939. Other than a few pits dug by the locators, little more had been done to prospect the deposits before investigation by the Bureau of Mines.

The Deposits

The general geology in the Bluebird area is similar to that in the other chromite-bearing areas along the ultramafic zone of the Stillwater complex. The average strike of the chromite band on the Bluebird Nos. 1 and 2 claims is, however, N. 75 E; the dip is 60 southeast. This deviation from the general strike and dip of the chromite band elsewhere along the ultramafic zone probably is due to a large south-dipping thrust fault that follows along the upper boundary of the ultramafic zone about 600 feet north of the chromite band.

The chromite band is narrow and low-grade in the western part of the area where the ultramafic zone also narrows. To the east, on the Bluebird claims, the chromite is found in minable widths of milling grade. The Bluebird No. 3 claim is detached and lies to the southwest of the other claims. Most of this claim is south of the lower contact of the ultramafic zone as mapped, therefore it is outside of the main chromite belt.

Work by the Bureau of Mines

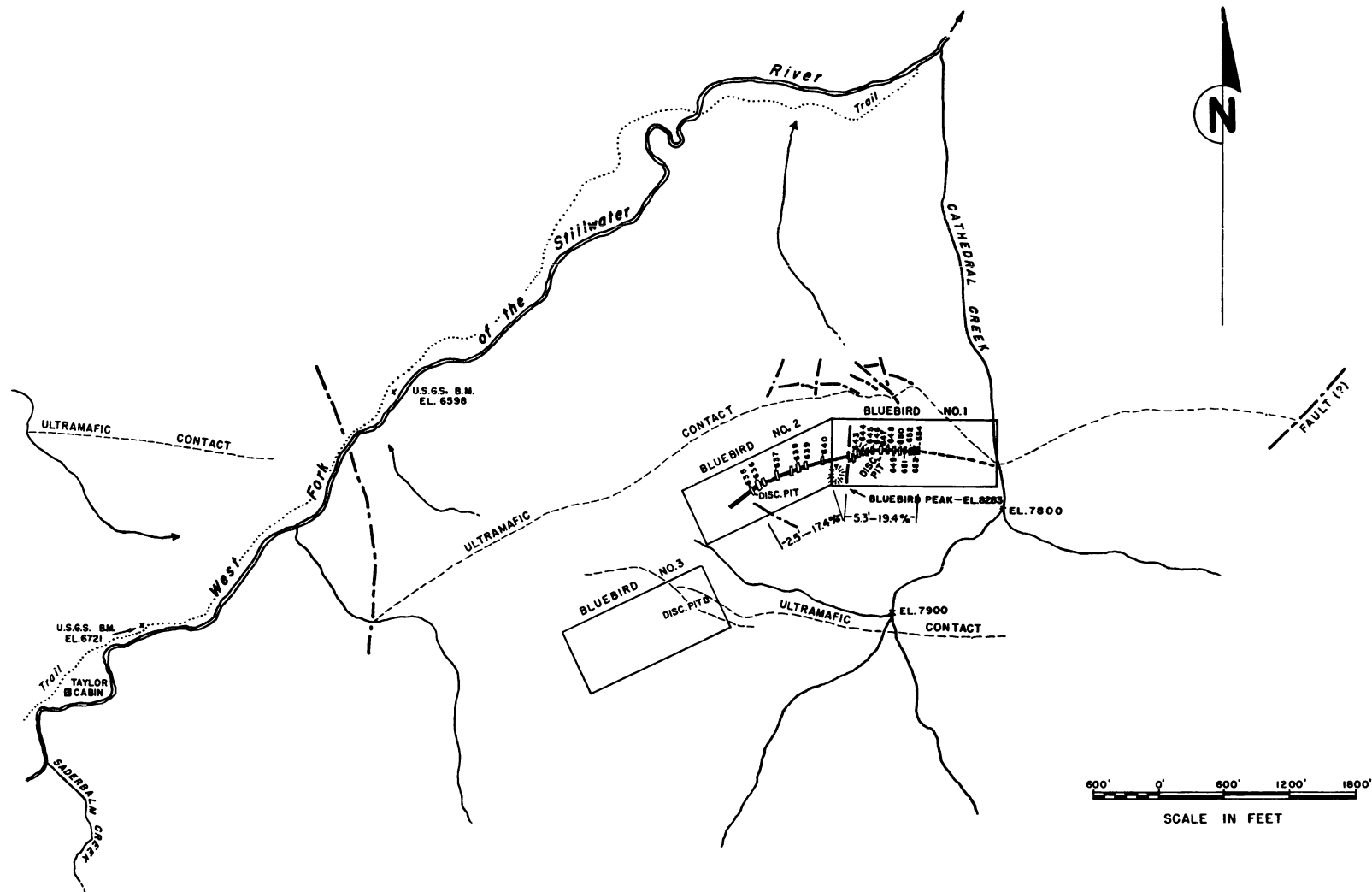
The Bureau of Mines began trenching and sampling on the Bluebird Nos. 1 and 2 claims early in July 1943. Eighteen trenches were dug, and all chromite exposures were sampled. The overburden was shallow at most of the trenches; but, eastward from point A to Cathedral Creek (fig. 19), it was too deep to be effectively trenched during the time then available. The chromite band, however, probably extends easterly through this section to and beyond the fault at Cathedral Creek, as chromite is again found to the east of that creek, although considerably offset by the fault. Several trenches also were dug west of point C in an attempt to trace the chromite to a lower altitude on the slope to the West Stillwater River. The overburden, however, was found to be too deep for effective trenching; nevertheless some chromite float was found in the gravel overburden.

The chromite band on the Bluebird Nos. 1 and 2 claims was trenched and sampled at intervals along the strike throughout a distance of 1,500 feet. It may continue to the west and also to the east of the trenched area. A fault has made a small offset of the chromite band at "B" (fig. 19). For a distance of about 200 feet west of "B", it was impossible to trace the chromite band because of difficult conditions; nevertheless, its continuity is indicated.

Section A-B as trenched and sampled is 3.6 to 7.6 feet wide and assays 3.6 to 21.0 percent chromic oxide. Throughout a length of 600 feet and an average width of 5.3 feet, the average chromic oxide content is 19.4 percent.

The chromite band in section B-C is exposed for a considerable distance along the face of a cliff. As exposed, trenched, and sampled throughout a length of 800 feet, section B-C has an average assay width of 2.5 feet and an average chromic oxide content of 17.4 percent.

The location and extent of the trenching are shown in figure 19. The trench-sampling results follow:



Exposed chromite. Bureau of Mines trenches. Indicated chromite continuity. Faults.

Based on aerial photograph and geologic mapping by U.S. Geological Survey

Figure 19. - Bluebird chromite deposit, Sweetgrass County, Mont.

Trench-sampling data - Bluebird area

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
635-1	1.8	24.93	647-1	3.0	39.33
			2	3.2	36.83
636-1	.9	19.67	3	1.0	3.33
2	1.5	12.95			
3	1.2	17.05	648-1	1.2	1.80
			2	2.0	30.50
637-1	1.9	24.22	3	3.0	7.63
2	2.0	5.18	4	1.3	1.90
638-1	.7	8.46	649-1	2.6	7.66
2	1.2	22.02	2	1.5	36.58
3	1.0	9.03	3	.8	1.71
639-1	1.3	26.44	650-1	2.0	4.56
2	1.4	16.60	2	1.0	5.27
			3	3.0	30.12
640-1	.9	26.03	4	1.0	16.02
643-1	3.0	10.81	651-1	1.7	8.30
2	1.8	6.47	2	2.0	34.51
3	1.5	3.15	3	1.8	2.04
644-1	2.4	24.91	652-1	2.1	12.85
2	1.5	9.29	2	2.7	35.68
			3	2.8	13.50
645-1	.7	32.29			
2	2.5	28.02	653-1	2.0	4.59
3	2.6	5.35	2	1.6	24.90
			3	2.1	2.92
646-1	.9	10.60			
2	1.6	19.72	654-1	2.0	32.00
3	.9	11.92	2	2.4	27.90
4	2.2	4.23	3	1.8	4.10

Taylor-Fry Area

The Taylor-Fry group of claims originally was located in 1917, 1918, and 1919 by a Mr. Dillon for the father of Clem and Bryan Fry. Those claims were abandoned and relocated several times. They were, in part, again located in 1938. At the death of the senior Fry, in 1938, his two sons took over and later were joined by W. A. Taylor. The Taylor-Fry group, as now held, consists of 11 lode claims and a placer claim located contiguously end to end along the main chromite band. Several other small bands and a mill site are covered by 10 side claims.

The S. J. Tuttle claims were located in June 1942. They adjoin the middle claims of the Taylor-Fry group at the south and are known as the Mountain View, River View, Dazzy View, and Valley View.

The Taylor-Fry group of claims is on the west side of the West Fork of the Stillwater River and extends from the river, at an altitude of 6,800 feet, up the west side of the canyon and across the plateau in a northwesterly direction to an altitude of about 9,500 feet. The total length of the group is about 4 miles. Before construction of a partly completed Forest Service truck road from the Mouat area, access to the Taylor-Fry area was by 6 miles of trail from the Mouat mine. This road now has been completed to within 3 miles of the Taylor-Fry property.

Except for some pits dug for claim location and protection, no mine work was done before trenching by the Bureau of Mines.

The Deposits

The general geology in the Taylor-Fry area is similar to that elsewhere along the Stillwater complex. Although the chromite bands in the Taylor-Fry group are relatively narrow, they show marked regularity in general strike and dip. The strike of the chromite bands averages about N. 75° W., and the dip ranges from 45° northwest at the eastern end to 60° northwest at the plateau level. The area from river level to an altitude of 7,100 feet, where the chromite first outcrops, is covered by heavy talus which cannot be effectively explored by trenching.

From the west end of the Groundhog claim, at an altitude of 7,100 feet and extending northwest for about 3,600 feet to an altitude of 8,600 feet at the west end of the Chipmunk claim, the chromite band, although offset by faults, shows great regularity and continuity. Here the chromite band generally consists of about 1 foot of massive and about 1.6 feet of disseminated chromite. The higher-grade disseminated chromite generally is on the hanging-wall side of the massive band. Some small segments in this locality were not trenched because of deep slides or overburden, but the continuity of the chromite in most of these segments is indicated (fig. 20).

No chromite outcrops or float have been found on the plateau on the Sirrus claim where, for a distance of about 1,400 feet, the overburden is deep. From the west end of the Sirrus claim to the east end of the Jupiter claim, a distance of about 2,600 feet, the chromite band has been exposed at several places.

As elsewhere along the ultramafic zone, numerous faults, generally trending northeast, cut the formation and offset the chromite band horizontally for 200 feet and more in some instances.

The chromite on the Tuttle claim occurs in several small stringers and as a disseminated zone of variable width. Continuity for any appreciable distance is lacking. The formation on these claims apparently corresponds to the lowest chromite-bearing horizon observed in the Mouat area.

Work by the Bureau of Mines

The Bureau of Mines started trenching and sampling the Taylor-Fry claims in May 1942. Over 15,000 feet of trails had to be built because of the steep slopes. Heavy snowfalls were experienced during May and June.

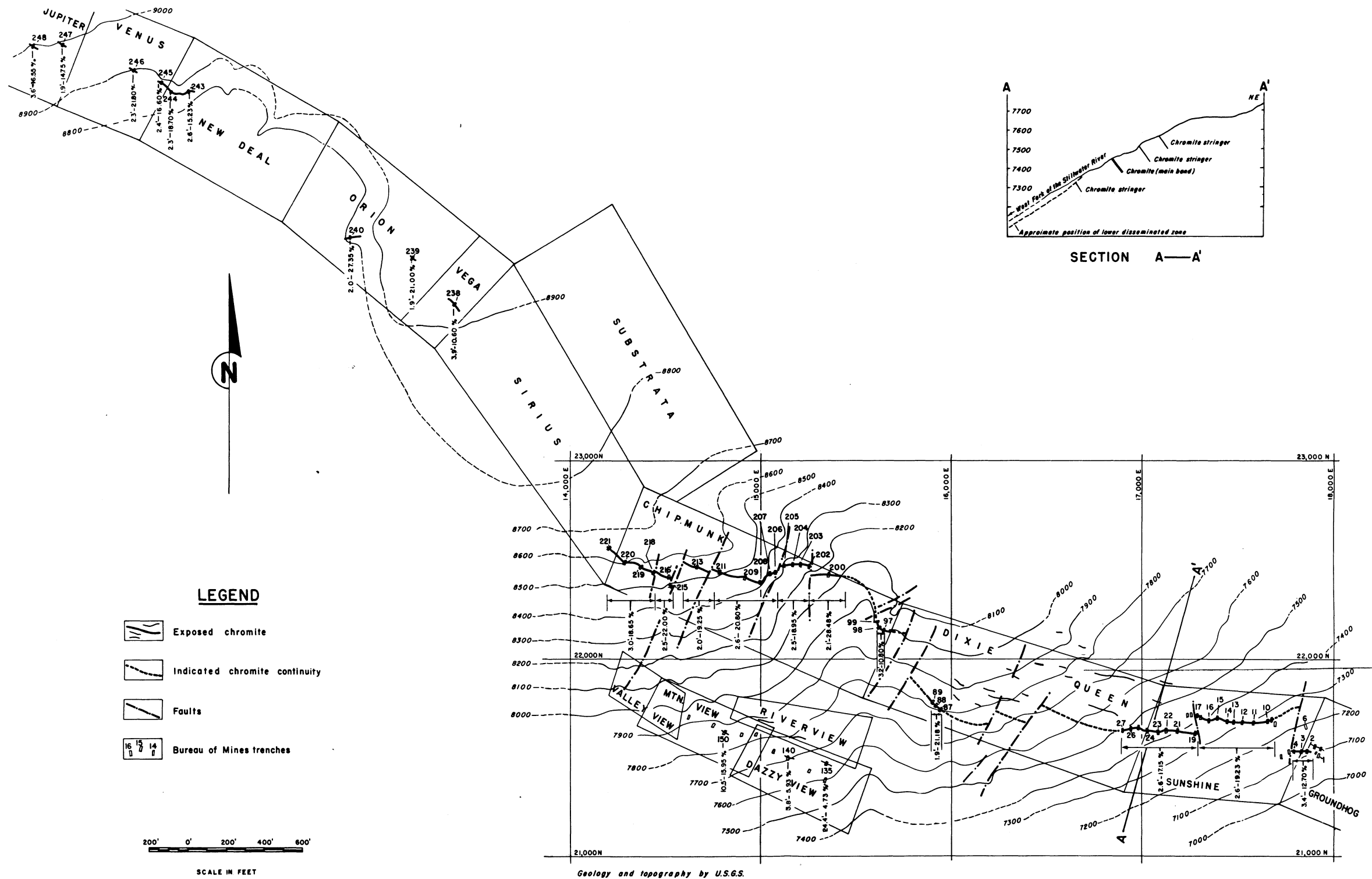


Figure 20. - Taylor-Fry-Tuttle deposits, Sweetgrass County, Mont.

The first trenching was done at 50-foot intervals throughout a distance of 1,000 feet along the strike of the chromite band. Very deep overburden was encountered at some places. Because a large territory was to be investigated, trenching later was confined mainly to areas near the top of the slopes and across the plateau where the overburden was shallow. All told, trenching and sampling were done at intervals for more than 8,000 feet along the general strike of the chromite (fig. 20).

The longest, most consistent and continuous segments of the chromite band extend northwesterly from the west end of the Groundhog claim into the Dixie Queen claim and across the Chipmunk claim into the east end of the Sirrus claim, throughout a distance of about 3,600 feet along the strike. On these claims, nine main segments, ranging from 100 to 540 feet in length, were exposed by trenching and by outcroppings.

The six segments on the Chipmunk claim have a combined length of 1,195 feet. Their assay width is 2.5 feet, and their average content of chromic oxide is 20.8 percent. The three segments between the west end of the Groundhog claim and the eastern part of the Dixie Queen claim have a combined length of 1,030 feet, with an average assay width of 2.7 feet and an average chromic oxide content of 17.6 percent.

From trench 200 on the Chipmunk claim eastward to trench 27 on the Dixie Queen claim, a distance of about 1,700 feet, outcrops are rare, and conditions for trenching are extremely difficult. Within this distance, the chromite band was exposed only in two groups of three trenches each. The two groups were about 900 feet apart. Nevertheless, the work indicated that, except for faulting, the chromite band is continuous across the unexplored gaps.

Eleven trenches were excavated on the Tuttle claims. Only four of these trenches exposed chromite. The best results were obtained in trench 150, where the chrome band assayed 15.95 percent chromic oxide across a width of 10.9 feet. Trenches both to the east and west of this trench failed, however, to show its continuity. In trench 135, the disseminated chromite zone was uncovered for a width of 24.4 feet and assayed 4.73 percent chromic oxide. Evidently the chromite bands on these claims are not continuous.

The location and extent of the trenching and average sampling results are shown in figure 20. The sampling results, by trenches, are as follows:

Trench-sampling data - Taylor-Fry area

Trench No. sample	Width sampled, ft.	Assay Cr_2O_3 , percent	Trench No. sample	Width sampled, ft.	Assay Cr_2O_3 , percent
<u>Groundhog claim</u>			3-1	1.2	20.00
2-1	0.8	8.46	2	2.0	4.93
2	1.0	34.33	3	1.0	3.38
3	1.0	8.98	4	.6	3.22
			5-1 .....	.4	14.89
			2 .....	.4	4.44

Trench-sampling data - Taylor-Fry area (Continued)

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
<u>Sunshine claim</u>					
4-1	0.6	1.74	23-1	0.7	14.83
2	2.5	15.13	2	1.8	24.65
3	1.5	4.97	3	.8	7.58
4	1.1	2.55	24-1	.9	33.25
6-1	.9	9.88	2	1.0	5.57
2	.7	2.17	<u>Dixie Queen claim</u>		
10-1	.7	27.79	26-1 .....	.9	22.75
2	1.5	6.84	2	1.2	9.00
11-1	1.2	40.08	27-1	1.1	30.45
2	1.5	8.27	2	1.5	7.00
12-1	1.0	33.27	87-1	.5	16.19
2	2.1	4.26	2	.5	39.95
13-1	1.1	33.91	3	.6	22.39
2	1.1	6.53	88-1	.5	22.46
14-1	1.1	30.87	2	.8	16.09
15-1	1.4	36.23	3	.5	7.48
2	1.4	10.38	89-1	.8	37.26
16-1	2.0	35.31	2	1.5	14.38
2	2.0	5.78	<u>Chipmunk claim</u>		
17-1	1.0	2.13	97-1	.8	3.37
2	1.3	29.04	2	1.3	37.67
3	1.5	4.60	3	.6	7.73
19-1	.5	3.09	98-1	1.2	16.98
2	.9	38.29	2	1.1	32.42
3	1.3	5.98	3	1.7	7.22
4	2.1	6.60	99-1	.8	14.96
21-1	1.0	35.92	2	.9	9.62
2	.5	16.54	3	1.3	8.75
22-1	1.0	33.05	200-1	.7	1.35
2	1.7	6.00	2	1.1	41.49
			3	1.0	14.18

Trench-sampling data - Taylor-Fry area (Continued)

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
<u>Chipmunk claim (continued)</u>					
202-1	0.3	5.78	219-1	0.7	2.53
2	.7	13.02	2	.8	39.60
3	1.6	10.18	3	1.1	10.28
203-1	1.1	41.15	220-1	1.1	1.73
2	1.2	8.88	2	1.0	39.67
204-1	.4	4.37	3	2.5	6.04
2	1.2	35.08	<u>Sirrus claim</u>		
3	1.0	6.90	221-1	1.3	2.35
205-1	1.4	32.58	2	1.7	32.53
2	1.3	7.24	3	2.2	9.42
206-1	.4	10.79	<u>Vega claim</u>		
2	1.4	37.23	238-1	1.1	1.73
3	1.0	8.44	2	.9	27.75
207-1	1.0	28.65	3	3.0	5.05
2	1.0	21.82	<u>Orion claim</u>		
208-1	1.0	5.71	239-1	1.1	4.20
2	1.0	31.40	2	.8	44.30
3	2.3	8.57	240-1	.7	34.75
209-1	1.1	24.93	2	1.3	23.40
2	.7	35.83	<u>New Deal claim</u>		
211-1	1.0	36.69	243-1 ....	.7	32.43
2	1.4	10.69	2	1.2	8.20
213-1	1.8	3.58	244-1	1.0	31.34
2	.9	34.93	2	1.3	8.95
3	1.1	6.47	<u>Venus claim</u>		
215-1	.8	1.16	245-1	1.3	4.05
2	1.0	33.79	2	.8	34.40
3	1.0	8.15	3	1.6	7.70
216-1	.7	1.52	246-1	1.4	30.80
2	1.8	32.17	2	.9	7.75
3	1.3	9.50	<u>Jupiter claim</u>		
218-1	1.0	1.01	247-1	1.1	22.50
2	1.0	36.99	2	.8	4.08
3	1.5	6.87	248-1	1.9	21.55
			2	1.7	11.00

Trench-sampling data - Taylor-Fry area (Continued)

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
<u>Tuttle claims</u>					
135-1	2.1	0.99	140-1	1.9	4.42
2	4.4	1.34	2	1.9	7.42
3	4.6	.69			
4	2.0	3.00	150-1	.5	3.86
5	2.3	29.81	2	1.3	9.02
6	4.4	3.49	3	1.6	7.81
7	4.0	2.19	4	2.2	4.06
8	2.7	2.89	5	2.7	10.76
			6	2.7	38.53
136-1	1.7	9.08	7	.9	2.47
2 .....	.9	29.40			
3	1.9	4.87			

Iron Mountain Area

The Iron Mountain area is just northwest of the Taylor-Fry area. All chromite showings on the Chrome group of 11 claims are on a rolling surface that extends across the highest part of the plateau from an altitude of 9,300 feet to one of about 10,000 feet. Extremely cold weather, high winds, and deep snow prevail during about 9 months of the year. The three summer months are cool and all the snow seldom disappears. Access to the claims is by 6 miles of steep trail from the West Stillwater Valley road. The Chrome group of claims was located in 1940. Some shallow test pits and trenches have been dug by the locators.

Work by the Bureau of Mines

The Bureau of Mines began sampling the chromite exposures on the Chrome group in August 1942. The available shallow pits and trenches were cleaned out and sampled. Thirty-two samples were taken from 15 different exposures. These were sufficient to indicate the size, character, and grade of the deposits. As the available time had become very limited by then, no new trenching was attempted.

Two narrow chromite bands and a wide, disseminated, low-grade zone occur in the area. Trenches 250 to 256 on the Chrome A, B, and C claims expose one band of chromite striking northwest. No chromite has been found in the 1,300 foot gap between trenches 250 and 254, apparently because of the deep overburden. Faulting also is indicated. As exposed in these trenches and as sampled, this chromite band ranges from 2 to 3.4 feet in width. Trenches 257 to 260 on the Chrome D claim expose a narrow and apparently different band, ranging from 0.6 to 1.4 feet in width. Both of these bands strike northwest and disappear under the overburden.

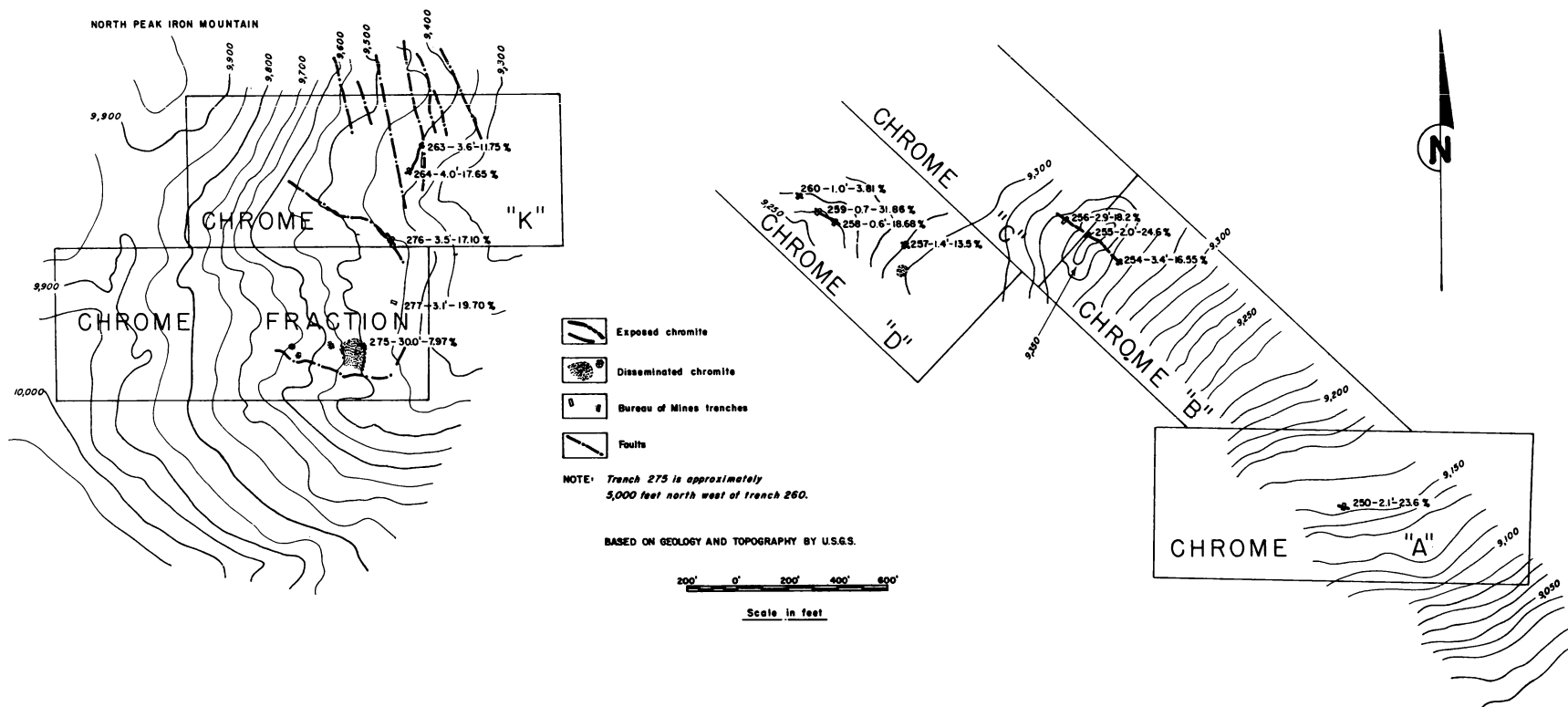


Figure 21. - Iron Mountain (chrome group) chromite deposits, Sweetgrass County, Mont.

Chromite is exposed again on the Chrome K and Chrome Fraction claims, which are about 5,000 feet northwest of trench 260 on the Chrome C claim. Here the chromite is found in one narrow band, several small stringers, and a disseminated zone. This area is cut by a series of faults that have offset, oriented, and badly fractured the chromite band. Most of the exposed chromite trends northeast, but the segment in trench 276 strikes northwest. The chromite band, as exposed, has an average assay width of 2.65 feet, and an average chromic oxide content of 17.9 percent. The disseminated zone is exposed in trench 275 for a width of 30 feet and averages 8.0 percent chromic oxide. It appears to be restricted to a relatively small area.

The location of the various trenches sampled is shown in figure 21. Details of the trench sampling and the assays are given in the following table:

Trench-sampling data - Iron Mountain area

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent	Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
250-1	0.9	39.40	259-1	0.7	31.86
2	1.2	11.85	2	.7	3.24
3	2.3	3.33	260-1	1.0	30.81
254-1	0.7	3.50	263-1	.6	37.92
2	.9	38.40	2	1.4	7.82
3	1.0	14.60	3	1.6	4.92
4	1.5	4.20	264-1	.8	31.78
255-1	1.0	39.57	2	1.4	20.31
2	1.0	9.67	3	1.7	9.37
256-1	.8	38.31	275-1	5.0	8.35
2	.8	10.20	2	5.0	7.60
3	1.3	11.17	276-1	3.5	17.10
257-1	.5	30.59	277-1	1.5	11.92
2	.9	4.05	2	1.6	27.10
258-1	.6	18.68			
2 ....	.9	2.94			

East Boulder River Area

The East Boulder River area extends westward from East Boulder River; it lies between the Iron Mountain and East Boulder Plateau areas. The altitude at the East Boulder River is 8,300 feet. The terrain to the west rises to an altitude of 9,300 feet in gentle, timbered slopes. Extremely cold weather and deep snow prevail during the greater part of 9 months. The area is accessible by Forest Service trails either from Boulder River or the Picket Pin trail, regardless of the route taken, it is 12 miles up steep trails from the nearest road. Chromite has been found at places in this area within a distance of

about 2-1/2 miles. The Chrome Queen group of claims was located in 1940, 1941, and 1942 by the Montana Chrome Corp. Some location pits and shallow trenches were dug by the corporation, but no underground development has been done.

Work by the Bureau of Mines

In August 1942, the Bureau of Mines cleaned and enlarged three of the discovery pits on the Chrome Queen Nos. 5, 6, and 9 claims. These pits are more than 1,000 feet apart but disclosed the best showings of chromite found in the area. Seven samples of the chromite exposed in these pits were taken. They indicated an average assay width of 3.3 feet and an average chromic oxide content of 22.6 percent. Other pits were cleaned out but disclosed no chromite mineralization that justified sampling. Extensive faulting, mainly by north-east trending faults, offsets the chromite band and, as in pit trench 265, has caused some overlapping. One segment on the Chrome Queen No. 9 claim is indicated to be 600 feet or more in length.

The location of the pit trenches and the sampling results are shown in figure 22. More details of the sampling are provided in the following table:

Trench-sampling data - East Boulder River area

Pit-trench no. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
265-1	0.9	34.61
2	3.0	13.23
3	2.6	2.70
266-1	1.2	29.45
2	1.2	8.50
267-1	.9	32.58
2	2.8	29.92

East Boulder Plateau Area

The East Boulder River Plateau area lies between the East Boulder River and the Gish areas, between altitudes 9,000 to 10,000 feet. Chromite is found in intermittently exposed outcrops and as float within a distance of several thousand feet. The area is accessible only by Forest Service trails from Boulder River or by the Picket Pin trail. The trail from Boulder River rises from an altitude of 5,000 feet to 10,000 feet with grades ranging to 35 percent. The Champion group of three claims was located about 1940. The only work done on the property by the locators consists of a few shallow pits.

Work by the Bureau of Mines

Four exposures of chromite in the Champion group of claims were trenched by the Bureau of Mines during August 1942, and seven samples were taken.

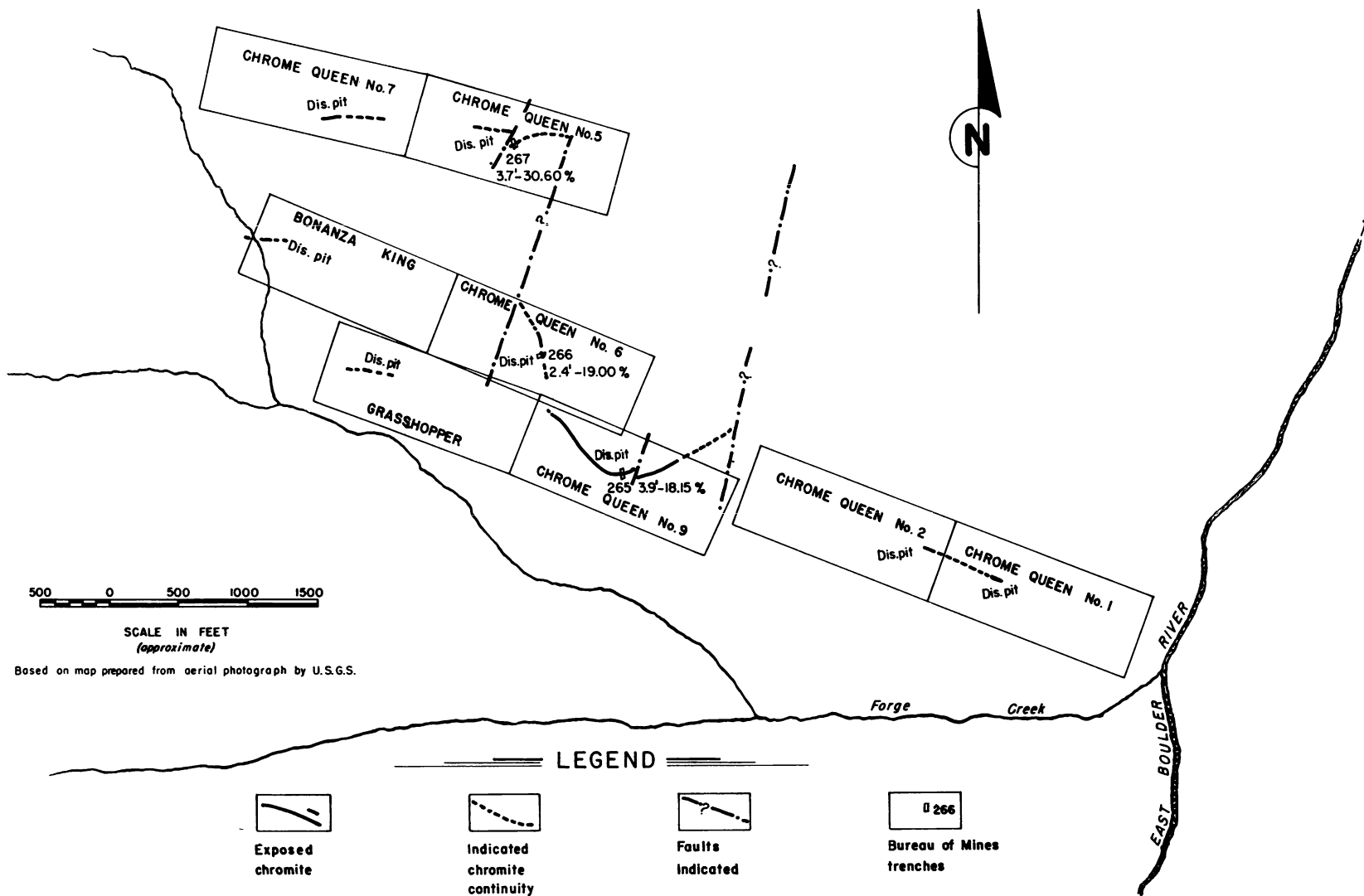


Figure 22. - East Boulder River (chrome queen) chromite deposits, Sweetgrass County, Mont.

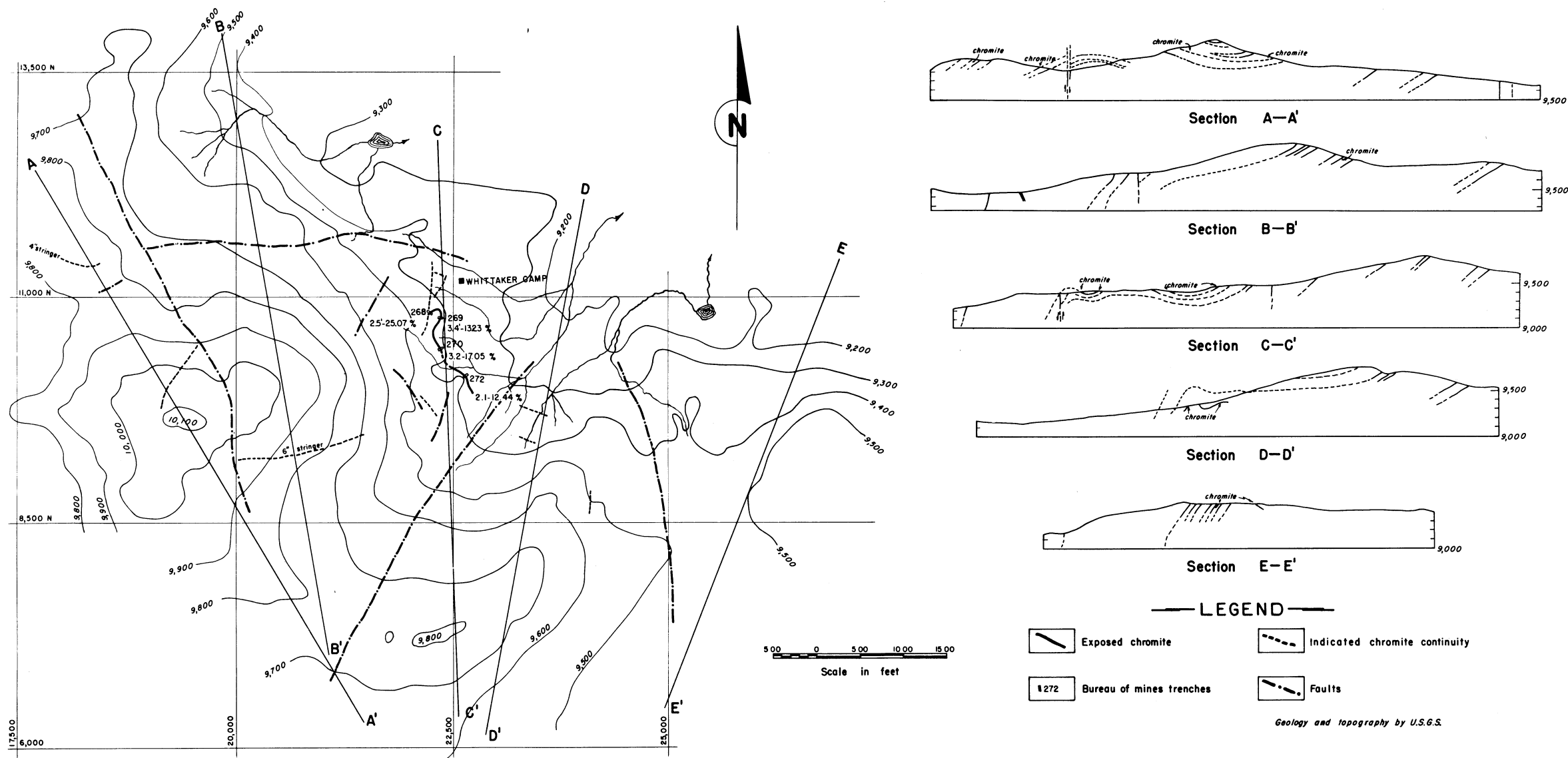


Figure 23. - Surface plan and cross sections of East Boulder plateau chromite deposits, Sweetgrass County, Mont.

Narrow bands and stringers of chromite also are exposed at various localities but were not sampled as they average less than one foot in width (fig. 23). The average assay width of the four trench exposures sampled was 2.8 feet; the average chromic oxide content was 16.8 percent. This area is faulted extensively but most of the faults have not definitely been located. The chromite band as exposed in the trenches has a general northwest, but rather deviating, strike and a relatively flat but variable dip. Continuity of the main chromite band within the area trenched is indicated for a distance of about 1,000 feet.

The location of the trenches, and the sampling results, are shown in figure 23. More details of the sampling are provided in the following table:

Trench-sampling data - East Boulder Plateau area

Trench No. sample	Width sampled, ft.	Assay Cr ₂ O ₃ , percent
268-1	2.5	25.07
269-1	2.5	5.51
2 .....	.9	34.70
270-1	1.3	10.78
2	1.9	21.36
3	1.1	1.65
272-	2.1	12.44

