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ARTHUR B. LANGLIE, Governor

Department of Conservation and Development
W. A. GALBRAITH, Director

DIVISION OF MINES AND GEOLOGY
SHELDON L. GLOVER, Supervisor

Report of Investigations
No. 18

MOLYBDENUM OCCURRENCES OF WASHINGTON

By

C. PHILLIPS PURDY, JR.

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FOREWORD

Molybdenite, the principal ore mineral of molybdenum, occurs rather commonly throughout the more favorable prospecting and mining areas of Washington and never fails to attract the attention of prospectors. Interest in this mineral goes back more than 50 years and has resulted in the staking of many claims and groups of claims. In some instances considerable development has followed, and four properties reached a stage of limited production of molybdenite alone. Various other properties are or have been considered as potential producers, and still more have molybdenite as an accessory mineral which may eventually have value as a byproduct of other mineral production.

Interest in molybdenum has increased in the past few years due to its inclusion by the Federal Government in the list of critical minerals of strategic importance. It is thought, therefore, that the present report will fill a need and be found useful by those engaged in mineral exploration and development in Washington.

The State Division of Mines and Geology is particularly appreciative of the permission granted by the United States Geological Survey to include in this account the results of investigations made by the Survey on the Starr and Western Molybdenum (Juno-Echo) properties. These two separate reports, one by Mr. S. C. Creasey and the other by Mr. John R. Cooper, have been available to the public only as "open file" reports in a few designated places. The inclusion, here, of this material, with the accompanying maps, adds immeasurably to the value of the present account of molybdenum in Washington.

SHELDON L. GLOVER, Supervisor,
Division of Mines and Geology

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By C. Phillips Purdy, Jr.

INTRODUCTION AND ACKNOWLEDGMENTS

For the past three decades the United States has been producing the major part of the world's molybdenum and during 1953 more than 90 per cent of the world supply, exclusive of Russia. Because of this phenomenal production there are at the present time no controls, either domestic or export, governing the sale or use of molybdenum, with the exception of those pertaining to the shipment of molybdenum in any form to Russia or her satellites. For these reasons, it appears at first glance to be an anomalous condition that molybdenum should be one of this nation's critical materials. However, when it is realized that the United States supplies the "Western World" with molybdenum, and that its uses, to be described later in this report, are increasing rapidly, it is not so strange that this element is listed as critical. With this situation in mind, it was considered that a survey of the possible molybdenum resources of Washington would be timely and of interest to the state's mining industry.

For several decades there have been rather persistent rumors regarding fabulous deposits of molybdenite in the state. During the course of this investigation all possible leads of this nature were run down, but, unfortunately, the accounts were found to be greatly exaggerated. Despite the large number of molybdenite showings, very few occurrences are sufficiently large and persistent to have possible commercial importance.

The investigation consisted of three parts: library review, field work, and laboratory work. All pertinent material in the files of the Division of Mines and Geology was reviewed, as was all published material that has a bearing on the project. The references to Washington molybdenum in the literature are scant and brief, but the United States Geological Survey has made two rather complete local studies, one on the Starr Molybdenum property west of Tonasket in Okanogan County and one on the Juno-Echo mine, east of Chewelah in Stevens County. As the results of both these investigations are given only in "open-file reports," the U. S. Geological Survey kindly granted permission to incorporate these two reports with that of the Division of Mines and Geology, thus making their findings more readily available to the public. The greater part of the library work had already been done and summarized by the Division in conjunction with the making of an inventory of all the metallic deposits in the state. The part of that inventory dealing with molybdenum is presented as an appendix in the back of this report and contains much valuable information. Most of this has been checked firsthand, either by the writer or by other members of the Division; but, due to the small quantity of molybdenite at some of the deposits, further detailed description was thought to be unnecessary.

The field investigations consisted of actually examining in the field all those properties that were indicated by the preliminary library work as warranting such attention and also running down as many as possible of the rumored occurrences, however mentioned. The detail in which the field mapping was done was dependent on the indicated importance of each property; i. e., whether there appeared to be any possibility at all of future production. For the most part, the molybdenum occurrences were of such small size and the mineralization had been so weak that this decision as to possible future production was not difficult. The amount of laboratory work for the project was also controlled by the same line of reasoning.

HISTORICAL SUMMARY

Molybdenum mining has always been of very minor importance in the state. The first published reference to molybdenite in Washington is given in the U. S. Geological Survey Mineral Resources volume for 1899. This report states,

> In Washington, near Skagit, and about 1,000 feet below the White Pass railroad tunnel, molybdenite is found in considerable quantity in a deposit 5 to 8 feet wide which has been uncovered for a distance of 800 feet. No determination of the percentage of molybdenite has been made. From the Castleman mine in the Mount Baker district, Whatcom County, occasional shipments of molybdenite ore have been made. In Okanogan County several deposits are reported, which are for the most part associated with copper; one in the vicinity of Lake Chelan is reported to be very rich.

This last-mentioned property is undoubtedly the Crown Point mine, but the other cited occurrences have defied detection and nothing is known about them.

Probably only four properties have ever had even a limited molybdenum production. The earliest of these was the old Crown Point mine at the head of Railroad Creek, west of Lake Chelan, Chelan County. It was discovered in either 1897 or 1898 and produced in 1901, 1902, and 1903. Only 25 or 30 tons of molybdenite was shipped during this period. However, the property did produce some of the finest crystals of molybdenite ever to be collected; one large cluster is reported to have weighed 300 pounds. In 1914 and 1917 the Crown Point property again produced a few pounds and then, after a brief period of development work in 1933, was finally abandoned.

In 1928 the Starr Molybdenum property was quite extensively explored by the Molybdenum Corp. of America, but evidently the results were not satisfactory, as they let the property go. However, in 1935 and 1936 the Titanium Alloy Manufacturing Co. took an option on the property and did further exploration and development work, only to let the property go on Jaunary 1, 1937. Then in 1939, according to Wilbur Starr, the owner, Carl Sundstrom sorted the dumps and reportedly shipped 3,000 tons of ore containing more than 1 percent molybdenite to his mill at Nighthawk, Washington.

In the summer of 1929 the Molybdenum Mines Co., of Yakima, Washington, was organized to prospect a property near Omak, Okanogan County, and another on the east side of Mount Rainier in the Deep Creek area in Yakima County. Only a small amount of molybdenite was ever found at this latter location. The Omak claims were carefully examined by the Division of Mines and Geology, and no molybdenite was identified, though about 1 percent molybdenum was reported to occur in a gneissic rock containing 3 to 4 percent graphite. Work was done at these locations until about 1931, and later, in 1937, a small additional amount of work was done at the property near Omak.

In 1934 the Deer Trail Monitor mine was put under development by J. Richard Brown of Spokane, Washington. This property was 9 miles east of Fruitland, Stevens County. It remained active until about 1940, a few tons of concentrates having been shipped in 1938.

In 1937 and 1938 the Consolidated Mines and Smelting Co., Ltd., explored at their property near Keller. They mined about 2,000 tons, from which some 5 tons of copper-molybdenite concentrate was made. This work was then suspended for several years.

Besides the above-mentioned properties, a few others have had small-scale sporadic development over the past 50 years. The locations of all properties that are known or have been reported to contain molybdenum are shown on the map of Washington (fig. 1 of this report). The properties are numbered separately for each county; a cross indicates that the principal metal at that place is molybdenum but does not necessarily indicate that the quantity is economic, and a dot indicates that the property contains molybdenum together with other metals. Lists of these properties are on page 11 and in the appendix at the end of this report.

According to the data gathered during this investigation, probably only two properties are worthy of possible consideration for their value in molybdenum alone. These are the Bi-Metallic and the Starr Molybdenum properties. As a byproduct, molybdenum might be produced from tungsten operations in the Germania area and from the Glacier Peak Copper property, were it ever to be operated, and lesser possibilities of this kind may exist at a few other properties.

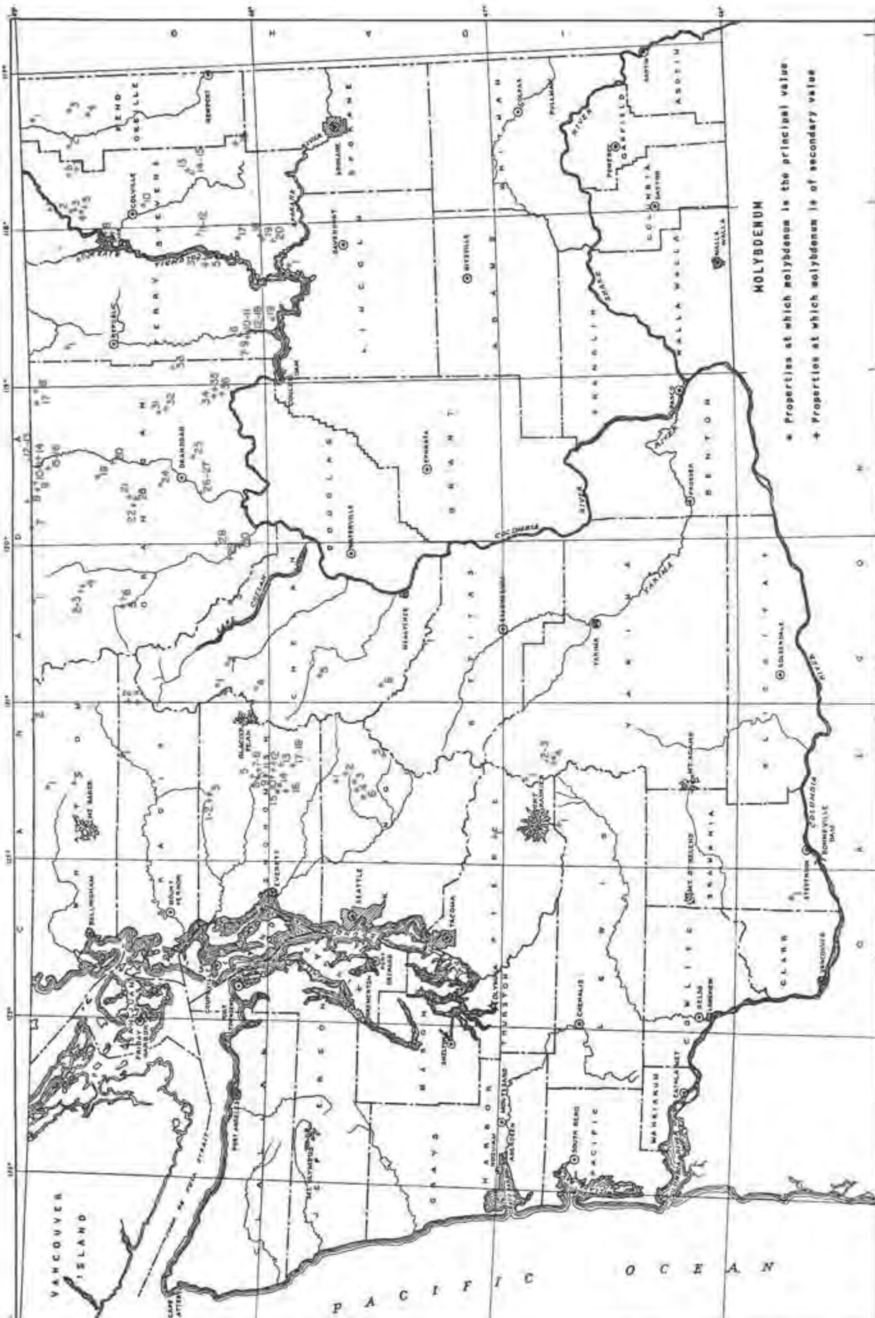

FIGURE 1—Index map showing molybdenum occurrences in Washington State.

Chelan County

1. Crown Point
2. Holden
3. Robischaud
4. Keefer Brothers
5. Merritt
6. Jack Creek

Ferry County

1. Kelly Camp
2. Barstow
3. Cold Spring
4. Big Chief
5. Rosario
6. Great Western
7. Abe Lincoln
8. Clay
9. Meadow Creek
10. Addie B
11. Mount Tolman
12. California
13. Handspike
14. Iconoclast
15. Illinois
16. Jumper
17. Polepick
18. Walla Walla
19. Schminski

Grant County

1. Electric City

King County

1. Monte Carlo
2. Bear Basin
3. Devils Canyon
4. Goat Mountain
5. Clipper
6. Lost Lode
7. Golden Eagle
15. St. Theresa
16. Kromona
17. Armament
18. Molly

Lewis County

1. Eagle Peak

Lincoln County

1. Spokane Molybdenum

Okanogan County

1. Sheep Mountain
2. Billy Goat
3. Carr
4. Hanks
5. Swayne
6. Molly
7. Horseshoe Basin
8. Golden Zone
9. Four Metals
10. Summit
11. Kaaba
12. Golden Chariot
13. O. K.
14. Moncosilgo
15. Spokane
16. Triune
17. Bi-Metallic
18. Eagle
19. Starr
20. Tonasket
21. Mineral Hill
22. Frankie Boy
23. Lady of the Lake
24. Green Lake
25. Corson
26. Malott
27. Rustler
28. Dutch John
29. Independence
30. Holden-Campbell
31. Hoot Owl
32. American Graphite
33. Wasco
34. Sterling
35. Twin Pine
36. Hudnut

Pend Oreille County

1. Polly Molly
2. Coffin
3. Little Noisy
4. Molybdenite Mountain

Pierce County

1. Golden Rule

Skagit County

1. Washington
2. North Coast
3. Skagit Queen

Skamania County

1. Miners Queen

Snohomish County

1. Sunrise (North Star, Oldfield)
2. Taylor and Nunn
3. Nesta
4. Glacier Peak
5. Silver Horseshoe
6. Copper Lake
7. Hustler
8. Rustler
9. Sunrise
10. Iowa
11. Sultan King
12. Mineral Center
13. Martin Engdahl

Stevens County

1. Short Wait
2. American
3. Lawrence
4. Ray Cox Moly
5. New Leadville
6. Sierra Zinc
7. Magma
8. Columbia River
9. Rightside
10. Rocky Lake
11. Columbia Tungsten
12. Washington Metals
13. Eagle
14. Chewelah Standard
15. Juno-Echo (Western Molybdenum)
16. Tungsten King
17. Deer Trail Monitor
18. Germania
19. Germania Consolidated
20. Sand Creek

Whatcom County

1. Midas
2. Silver Creek
3. Sulphide Creek

Yakima County

1. Chinook
2. Bird
3. Copper Mining Co.
4. Crosetti

PROPERTIES, USES, AND MARKETING OF MOLYBDENUM

PROPERTIES

Pure molybdenum is a silvery white, tough, malleable metal resembling platinum. Impurities cause it to be brittle and to turn a darker color. The pure metal has the following physical properties:

Crystalline form	Cubic
Hardness (Moh's scale) depending on contained impurities	5.5—8.5
Specific gravity	10.2
Atomic weight	95.95
Melting point	2622° C ± 40° C
Boiling point	4804° C
Coefficient of linear expansion	5.7×10^{-6} per degree C
Electrical resistance at 27° C	5.78 microhm-cm
Thermal conductivity at 17° C	0.346 cal./cm^2/°C/sec.
Specific heat at 25° C	0.058 cal./gm/°C
Tensile strength	260,000 lb. psi.

Metallic molybdenum is now prepared by the Climax Molybdenum Co. by casting 9-inch, 1,000-pound, high-purity ingots in a special vacuum-arc furnace. The pure metal can be forged white hot, filed, polished, and drawn into wire. Perhaps the greatest drawback to the use of this metal is that it has a great affinity for oxygen and oxidizes slowly in air at a dull-red heat and more rapidly as the temperature is increased. Chemically, molybdenum is a reasonably active metal, combining directly with fluorine at room temperature and with chlorine and bromine at progressively higher temperatures. Concentrated nitric and sulfuric acids react with the metal, but dilute hydrochloric and sulfuric acids do not. Fused oxidizing salts such as potassium nitrate, potassium chlorate, and sodium peroxide vigorously attack it. However, the fused alkalies act upon it slowly. Molybdenum combines directly with nitrogen, phosphorus, carbon, silicon, sulfur, and boron in addition to those elements mentioned above. Actually, the nitrogen has very little tendency to combine with the annealed metal, but the unannealed metal when hot absorbs the gas, forming an unstable nitride. Also, molybdenum takes up carbon at 1000° C and attains sufficient hardness to scratch steel.

The compounds of molybdenum aside from molybdic oxide and calcium molybdate have little or no use outside the chemical industry.

USES

As molybdenum possesses a high melting point and good tensile properties, it finds many uses, principally as an alloying element to increase the strength, toughness, ductility, and resistance to heat and corrosion of steels. Also, it improves their workability at higher temperatures. In the U. S. Bureau of Mines Minerals Yearbook for 1949, H. W. Davis, discussing the uses of molybdenum, mentions the following:

> The largest single use for molybdenum is as an alloying element in the manufacture of steels, to which it is added as molybdic oxide, calcium molybdate, or ferromolybdenum. In general, when an entire open-hearth heat is to be alloyed to a degree not exceeding 0.8 percent molybdenum, the addition is in the form of molybdic oxide or calcium molybdate; ferromolybdenum is used when higher percentages of molybdenum are desired. Of the total molybdenum used in the United States, it is estimated that about 70 percent is in steels. The addition of molybdenum to conventional 18:8 (18 percent chromium and 8 percent nickel) stainless steel has, it is reported, (†) produced a popular casting alloy with improved corrosion resistance and increased strength at elevated temperatures. Molybdenum is finding an expanding market in the high-temperature alloys developed for various components of gas turbines, as well as in jet aircraft engines and turbosuperchargers. Use of tungsten-molybdenum thermocouples in the study of high-temperature alloys is reported (‡) to have resulted in improvement of the range of satisfactory service up to 3990° F. It is also reported (♦) that both the oxidation resistance and strength of molybdenum may be improved by making certain alloying additions and that such alloys can be successfully arc-melted and cast in an argon atmosphere. High-temperature ceramic coatings for molybdenum have been developed.
>
> Much smaller quantities (about 20 percent of the total) of molybdenum, chiefly in the form of ferromolybdenum and molybdic oxide, are employed in gray iron and malleable castings. Molybdenum in various forms finds limited employment in the chemical, electrical, and ceramic industries, which account for about 10 percent of the total. A relatively small quantity of concentrates (50,000 to 75,000 pounds of contained molybdenum annually) is used by a few steel companies as an addition to molten metal in the ladle to raise the sulfur content to improve machinability, in addition to gaining the benefit of the contained molybdenum. Molybdenum is being used with remarkable success as a fertilizer, and it is reported that certain crop yields have doubled as a result of minute additions to the soil.

In addition to the above mention of high-temperature ceramic coatings, it is interesting to note that a silicon coating for high-purity

(†) Mott, N. S., Molybdenum-bearing stainless casting alloy has wide range of uses: Materials & Methods, vol. 30, no. 1, July 1949, pp. 50-53.

(‡) Potter, R. D., and Grant, N. J., Tungsten-molybdenum thermocouples: Iron Age, vol. 163, no. 13, Mar. 31, 1949, pp. 65-69.

(♦) Iron Age, Arc-melting molybdenum-rich alloys: vol. 164, no. 24, Dec. 15, 1949, pp. 82-83.

metallic molybdenum has been developed that is stable up to 1760° C. However, there is still a tendency to brittleness. Another item of interest is the capability of molybdenum to plate itself on friction surfaces and endure high temperatures and pressures. These characteristics have resulted in the development of an excellent lubricant for certain purposes.

Other interesting uses for molybdenum are in radio and radar equipment, where it is used as filaments and plate elements in radio and power tubes.

Small amounts of molybdenum salts are used to increase adherence in ground coats for enamels to cover steel and iron and to produce pigments of varying shades from blue through green to dark brown for dyes and inks. As a chemical reagent ammonium molybdate is employed for making phosphorus determinations in steels.

MARKETING

According to the U. S. Bureau of Mines, in 1952 a total of 16,357.5 tons of molybdenum was consumed in the United States and 21,633.2 tons produced. In 1953 the production of molybdenum increased 36 percent over 1952. Compared with figures for the past 4 years this shows a general continuing upward trend in both production and consumption. At the end of 1952 a total of 3,428 tons was held in the stockpiles at the mines and plants manufacturing molybdenum products.

The continued increase in the consumption of molybdenum is reflected in the firm price of molybdenite concentrate containing 90 percent MoS_2 at 60 cents per pound of contained molybdenite (1954). Also, as a further indication of these increases, molybdenite is on the list of this nation's critical basic materials, and under the D.M.E.A. program the Federal Government will grant a 50 percent matching loan to private industry for exploration projects on potential molybdenum deposits. This ruling went into effect November 3, 1953.

In spite of increased production by the Climax Molybdenum Co. in Colorado in 1954 and new copper and molybdenum production from Arizona and Nevada coming in during 1954 and expected in 1955, the 1954 price of molybdenite concentrate will undoubtedly remain firm with the continuing increased worldwide use of molybdenum for the development of high-temperature metals.

As the molybdenum deposits in the state of Washington are of small size compared to the large low-grade deposits from which the bulk of the United States molybdenite concentrates come, buyers of concentrates who are interested in small lots are important to the potential Washington producer. As of 1953 the following concerns were purchasing molybdenite concentrates, the ones marked by an asterisk being the firms most likely to make purchases in small lots.

Name	*Address*
*J. T. Baker Chemical Company	Phillipsburg, New Jersey
Climax Molybdenum Company	500 Fifth Avenue New York 18, New York
Electro Metallurgical Company, a Division of Union Carbide & Carbon Corporation	30 East 42nd Street New York 17, New York
Fansteel Metallurgical Corporation (Att.: C. N. Washburn)	North Chicago, Illinois
General Chemical Division Allied Chemical & Dye Corporation	40 Rector Street New York 6, New York
General Electric Company	1 River Road Schenectady 5, New York
Alan Kissock & Company	70 Pine Street New York 5, New York
Miami Copper Company	Miami, Arizona
Molybdenum Corporation of America	500 Fifth Avenue New York 18, New York
Republic Steel Corporation	Republic Building 25 Prospect Avenue, N. W. Cleveland 1, Ohio
*S. W. Shattuck Chemical Company	1805 South Bannock Street Denver 10, Colorado
*Sterling Drug, Inc. Hilton Davis Chemical Company	Pleasant Ridge Station P. O. Box 8 Cincinnati 12, Ohio
United States Vanadium Corporation, a Division of Union Carbide & Carbon Corporation	30 East 42nd Street New York 17, New York

The Government also purchases concentrates according to their official stockpiling specifications for molybdenite, which are given below as of June 13, 1951.

CHEMICAL REQUIREMENTS

Molybdenum disulphide, MoS_2, (molybdenite)
Each lot of molybdenite shall conform to the following:

		Percent by weight molybdenite
Molybdenum disulphide	(MoS_2)	80.00 minimum
Copper	(Cu)	1.00 maximum
Lead	(Pb)	0.30 maximum
Phosphorus (P), Tin (Sn), Arsenic (As)	Combined	0.20 maximum

PACKAGING

Material shall be packed in metal containers, or hardwood barrels or kegs. Containers may be of any size usual with the producer, but all containers comprising any given lot shall be of the same nominal size and shape.

INSPECTION

Material shall be subject to inspection and analysis by the purchaser or his designee.

Though most government purchases for the stockpile have involved large quantities, there is no regulation preventing the purchase of small lots, and it is likely they would be acceptable. Information requests regarding the purchase of molybdenite concentrates for stockpiling should be addressed to General Services Administration, Emergency Procurement Service, Washington 25, D. C.

It would be advisable to correspond with one and preferably more of the above potential buyers before making expenditures on a molybdenite venture, because it is probable that molybdenite concentrates will be difficult for small operators to market and that the quantity, price, and grade of concentrate that is acceptable will fluctuate. For instance, all concentrate is bought on a 90 percent molybdenite basis, the price being $0.60 per pound of contained molybdenite, thus anyone offering less than a 90 percent concentrate would be penalized by a lower price. However, according to the U. S. Bureau of Mines, concentrates having a molybdenite content varying from 57 to 94 percent are shipped.

The question of what is a minable grade of molybdenum ore under present economic conditions is a difficult one to answer. There are two factors to be considered: price, and tonnage of ore that can be consistently mined per day. As to the former factor, the price of molybdenum for the past 25 years has been relatively steady; it has shown a persistent increase in the past 4 years. Thus, extrapolating, the present price as previously discussed can probably be counted on to at least stay at the present level. Consequently, a price of $0.60 per pound of contained molybdenite in a 90 plus percent concentrate can be assumed. The relationship of tonnage to grade and this latter to the present price and mining-cost conditions is well brought out by the following observations. Currently the molybdenite content of ore mined in the United States ranges from 0.4 to 1.5 percent. The lower figure probably represents the large tonnage operation (27,000 tons/day) of a disseminated deposit, whereas the higher figure probably represents the lower tonnage operation (250 tons/day) of a vein deposit. In the state of Washington, as a relatively small operation would have to be assumed, the higher figure of 1.5 percent molybdenite would undoubtedly be a very minimum grade, and a grade of at least 3 percent would be necessary to encourage a new molybdenite operation. Even with a grade such as this a sizable potential reserve would be necessary.[1] It is interesting to note, as an example of what can be done, that at the Knaben mine near Egersund on the southwestern coast of Norway, the ore contains 0.15 to 0.20 percent molybdenite and is concentrated by flotation to a 95 percent concentrate. This of course would hardly be economical in the United States.

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[1] See discussion of the Questa deposit on page 43.

THE COMMON MOLYBDENUM MINERALS AND THEIR IDENTIFICATION

There are but four common molybdenum-bearing minerals: molybdenite, wulfenite, powellite, and ferrimolybdite (molybdite). Of these, molybdenite is the usual ore mineral. However, a small production has come from wulfenite and powellite.

MOLYBDENITE

Molybdenite (MoS_2) is found widely scattered through the mining districts of Washington. The two most important molybdenite deposits appear to be the Starr Molybdenum mine and the Bi-Metallic mine, both in the vicinity of the town of Tonasket.

Molybdenite is a soft (hardness 1.0 to 1.5) flaky lead-gray mineral with a metallic luster. When pure—and it rarely contains trace elements as impurities, although germanium has been reported—molybdenite contains 59.94 percent molybdenum and 40.06 percent sulfur. The mineral has basic cleavage, and its crystals are hexagonal and commonly tabular.

Usually, the physical properties provide adequate data upon which to identify the mineral, but a specific chemical test may be desirable. Probably the simplest test for molybdenum is to powder a small bit of the suspected mineral and heat it to dryness in a test tube with concentrated nitric acid. This reaction transforms the mineral to a white to grayish residue. At this stage the test tube near the residue has a deep blue coating if the mineral is molybenite. After the tube is cooled to room temperature, a few drops of concentrated sulfuric acid are added and the test tube is again heated until only a little acid remains in the tube. It is then cooled and the fumes allowed to subside, after which blowing one's breath into the tube reduces the white to gray oxide (MoO_3) to a brilliant blue (Mo_2O_5) visible around the sides of the tube. The solution itself is a bluish green, indicative of the still lower trivalent oxidation state (Mo_2O_3).

It is often difficult to distinguish between molybdenite and graphite, particularly when they are fine grained. Probably the best way to tell them apart is to test with hot concentrated nitric acid. The molybdenite reacts with the acid and leaves a residue of white molybdenum oxide, but graphite is inert. Also, graphite gives a dark steel-gray to black streak on glazed porcelain, whereas the molybdenite streak has a greenish cast. Besides these properties, graphite has a specific gravity of 2.09 to 2.23, which is less than half that of molybdenite at 4.62 to 4.73. The use of specific gravity is not too valuable a method for distinguishing the two unless a relatively large piece of each is to be had or laboratory apparatus such as a pycnometer is available. Finally, molybdenite on a *fresh* cleavage surface shows, for just a moment, a brilliant purplish hue, which is lacking in graphite.

It is most important, when having molybdenum ore assayed, that the work be done by people familiar with the many problems involved. Though the process is not overly complicated, experience is essential for dependable and consistent results.

WULFENITE

Wulfenite ($PbMoO_4$) is the ore mineral at the old Mammoth mine in Pinal County, Arizona, but to the writer's knowledge its only reported occurrence in Washington is at the New Leadville[2] property, Stevens County, where it was present in the weathered zone.

Wulfenite is a brittle, moderately soft (hardness 3), waxy mineral varying in color from orange to green and occasionally gray or brown. It crystallizes in the tetragonal system; the crystals have pyramidal cleavage and are commonly square tablets, which may be extremely thin. It also occurs in the massive form. Wulfenite has a high specific gravity ranging between 6.7 and 7.0, and, when pure, it contains 56.4 percent lead and 26.1 percent molybdenum.

According to Peterson[3] wulfenite can be of hypogene origin as well as supergene. However, its mode of origin is peculiar, and for that reason the mineral is not a common ore. Dittler,[4] on the basis of chemical experiments, concluded that wulfenite can be formed by ascending molybdenum-bearing alkaline solutions reacting on lead carbonate which had previously been formed by descending surface waters carrying H_2CO_3 acting on galena. Because an origin based on precipitation from ascending hydrothermal solutions can be postulated, instead of one based on intense oxidation, it is not impossible for additional wulfenite to be found in Washington, but more than likely it would be only as specimen material, such as the New Leadville occurrence.

POWELLITE

Powellite [$Ca(Mo,W)O_4$] has been reported as occurring in the state, but none was found during this investigation. It is a moderately hard (hardness 3.5) yellow mineral with pyramidal cleavage. Its color may also be pale green and white to gray. However, these properties are usually of little use in determining it, as it customarily

[2] Jenkins, Olaf P., Lead deposits of Pend Oreille and Stevens Counties, Washington: Washington Div. Geology Bull. 31, pp. 115-117, 1924.

[3] Peterson, N. P., Geology and ore deposits of the Mammoth mining camp area, Pinal County, Arizona: Arizona Bur. Mines, Geol. Survey No. 11, Bull. 144, 63 pp., 1938.

[4] Dittler, E., Further experiments on the synthetic production of wulfenite: Zeitschr. Kristallographie, Band 54, pp. 332-342, 1914.

occurs in the oxidation zone in minute earthy tetragonal crystals and as a replacement product of molybdenite. Ordinarily, identification is most easily made by observing the golden-yellow fluorescence of powellite under ultraviolet light. The mineral with which it is most easily confused, ferrimolybdite, has a bright yellow color and fibrous structure. Also, powellite and ferrimolybdite have never been observed occurring together.

It has long been thought that tungsten is an essential constituent of powellite, but work by Vanderwilt[5] showed that this is not necessarily the case. Too, powellite has normally been thought of as only an oxidation product, but work by Knopf[6] in Nevada shows that powellite can also originate as a primary mineral from hypogene solutions.

FERRIMOLYBDITE (MOLYBDITE)

Ferrimolybdite [$Fe_2(MoO_4)_3 \cdot 8H_2O$?] is the common yellow oxidation product of molybdenite. It crystallizes in the orthorhombic system and is soft (hardness 1.5) and fibrous. The yellow color is often pale and is easily mistaken for an oxidation product of pyrite, but the association with molybdenite, which is always present, indicates the true origin. Ferrimolybdite is often associated with limonite, and if the limonite is yellowish the ferrimolybdite may be particularly difficult to detect without a chemical test. Because of the fact that molybdenite is comparatively stable, very little ferrimolybdite has an opportunity to form, particularly in a cool temperate climate such as Washington has. However, it does occur in small amounts in eastern Washington molybdenite deposits.

THE GEOLOGIC ENVIRONMENT OF MOLYBDENITE AS AN AID TO PROSPECTING

From the subsequent discussions of the individual molybdenite deposits in the state, some generalizations may be made. Molybdenite has a strong affinity for granitic rocks of siliceous nature. In fact, probably 75 percent of the occurrences the world over are associated with rocks of this kind.[7] In Washington all the molybdenite occurrences seem to show this relationship to sialic rocks, though a given deposit may be in any one of a variety of rock types. To generalize further, there are two principal types of molybdenite deposits, those with a pegmatitic affiliation and those with a hydrothermal affilia-

[5] Vanderwilt, J. W., Occurrence and production of molybdenum: Colorado School of Mines Quarterly, vol. 37, no. 4, p. 28, 1942.

[6] Knopf, A., The Divide silver district, Nevada: U. S. Geol. Survey Bull. 715-K, pp. 158-160, 1921.

[7] Horton, F. W., Molybdenum; its ores and their concentration: U. S. Bur. Mines Bull. 111, p. 8, 1916.

tion; i. e., in quartz veins and/or areas of staining and/or bleaching. Molybdenite deposits of the former type are, as a general rule, too small to mine at a profit under present economic conditions. The most promising deposits occur in granitic rock as disseminations of hydrothermal origin. Vein deposits carrying molybdenite are usually of less economic interest. Actually, a considerable percentage of molybdenite is produced as a byproduct from occurrences in close association with both copper and tungsten. It is being currently produced in this way at the large disseminated copper deposits of hydrothermal origin in Utah, Nevada, and Arizona. In Washington the Glacier Peak Copper deposit (see p. 63) is one of this type. Molybdenite is also currently recovered as a byproduct of a tungsten operation at Bishop, California, where it occurs between granite and metamorphics in a tactite, which has been mineralized with scheelite, molybdenite, chalcopyrite, and bornite. In Washington, molybdenite could possibly be recovered as a byproduct of the tungsten operation at the Germania Consolidated Mines, Inc. (see p. 70).

An important generalization regarding ore deposits that may apply in Washington has been brought to the writer's attention;[8] namely, that the type of batholith that produces pegmatites (microcline-bearing, very lean in femic minerals, but containing much epidote) usually does not produce ore deposits of the common base metals. However, tin, tantalum, columbium, beryllium, lithium, rare earths, tungsten, and extremely minor amounts of certain sulfides of molybdenum, bismuth, copper, and iron are commonly associated with this type of batholith. As the granitic rocks of the state generally lack pegmatites, contain femic minerals, and have only small amounts of microcline and epidote, they appear to be of an appropriate composition for the development of sulfide mineral deposits.

Considering the above geologic generalizations as applying to the occurrence of molybdenite, the northern half of the state of Washington is favorable for prospecting. Narrowing the area still further, the following counties would bear investigation, because of their essentially granitic and metamorphic terrane: the eastern half of Whatcom, Skagit, Snohomish, and King Counties, the northwestern part of Kittitas County, all of Chelan, Okanogan, Ferry, Stevens, and Pend Oreille Counties, and the northeastern part of Spokane County. South of Snoqualmie Pass along the Cascade crest the rocks are largely andesitic volcanics; however, there are three areas of Tertiary granitic intrusions in this region that might repay prospecting, as molybdenite has already been described as occurring with them. These are: (1) southwestern Skamania County, (2) 16 miles west of Stevenson in northwestern Skamania County, extending north of Spirit Lake for 6 miles, and (3) to the northwest and

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[8] Hall, W. E., Personal communication.

south of Bumping Lake in Yakima County. It can readily be seen that the areas just mentioned as favorable for prospecting conform to the distribution of molybdenite occurrences as spotted on the index map (see fig. 1 on p. 10).

As to actual methods of prospecting, there are, besides the time-honored method, "seek and ye shall find," two main procedures available which have a sound scientific background: geophysical and geochemical. However, neither of these methods is of use until a potential area has been located, presumably by prospecting a suitable granitic terrane. Thus, the principal advantage of the geophysical and geochemical techniques is to provide a thorough and systematic coverage of an area in which molybdenite has been found in a favorable geologic environment, even though the original molybdenite discovery itself may not appear to have commercial potentiality.

Of the geophysical methods, the most satisfactory for use with molybdenite deposits are the various electrical techniques, which are well described in the standard geophysical textbooks; of these books perhaps the best modern one is Exploration Geophysics, 2nd ed., by John J. Jakosky, Trija Publishing Co., 1950.

In 1927 Karl Lundberg made an electromagnetic survey for molybdenite near Questa, New Mexico;[9] the results of this survey were very successful, and proved that this method was useful in locating small veins with poor conductivity in country of very rugged topography. The conductivity of the molybdenite veins varies, but generally is 10,000 to 30,000 ohms per cubic centimeter, while that of the country rock is 1,000,000 ohms per cubic centimeter. The geology of the Questa deposit is discussed in this report on page 43.

Various techniques for geochemical prospecting have been worked out. These can be divided into four classes, according to the type of material from which samples are taken for chemical analysis; namely, the bedrock or its weathered counterpart, vegetation, glacial till, and soil. This last can be particularly complex because of the many varieties of material from which the soil may form, and also the manner in which the soil forms from these materials.

The fundamental principal upon which geochemical prospecting is based is the fact that the element sought, and presumably contained in a deposit, will be present in the soil or plant matter associated with that deposit in amounts that vary inversely with the distance from the source; i. e., the closer to the source, the greater the concentration of the element. Because of this fact a

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[9] Lundberg, K., and Nordstrom, A., Electrical prospecting for molybdenite at Questa, New Mexico: Am. Inst. Min. Met. Eng. Trans., Geophysical Prospecting 1929, pp. 125-137.

grid may be laid out and the concentration of the element determined at points on the grid by very sensitive methods of colorimetric analysis. After the concentrations have been spotted on the grid they may be contoured, and thus the presence or absence of a deposit can be shown by the presence or absence of an anomaly. The distance beneath the surface at which soil samples should be taken is subject to the conditions of soil formation and the relationship of the topography to the deposit. However, 6 inches is the depth quite commonly used. Again, the distance separating the individual grid points depends upon the particular topographic and soil conditions at a given deposit; 50- to 100-foot intervals are not uncommon. Experience has shown that soil sampling, though showing the presence of a possible metal deposit, will give no indication as to the grade of that deposit. Huff[10] has pointed out pertinent aspects of sampling techniques in an excellent article, which should be studied by anyone contemplating geochemical prospecting. Particular attention should be paid to the effect of topography and nonresidual soils. Briefly, topography appears to exert the same control over a geochemical anomaly that it does over soil creep, and in areas covered by nonresidual soils geochemical anomalies will differ greatly from those developed in residual soil.

Another general article discussing these techniques, written by H. E. Hawkes of the U. S. Geological Survey, is Geochemical Prospecting for Ores. It is to be found in the book Applied Sedimentation, Parker Trask, Editor. John Wiley and Sons, Publisher, 1950. The method of chemical analysis as used for molybdenum in these techniques is described in an "open file" report by the U. S. Geological Survey which may be seen in the office of the Division of Mines and Geology at Olympia, Washington, or in any of the regional offices of the U. S. Geological Survey. In the state of Washington the regional office of the Survey is at 157 S. Howard Street, Spokane.

Though geophysical and geochemical methods may appear to be basically simple and perhaps are, their application to actual field problems is highly complex. For this reason such work should be done only by thoroughly trained and experienced personnel, otherwise erroneous data and false conclusions will inevitably result.

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[10] Huff, Lyman C., Abnormal copper, lead, zinc content of soil near metalliferous veins: Econ. Geology, vol. 47, no. 5, pp. 517-542, 1952.

MOLYBDENITE OCCURRENCES INVESTIGATED

CHELAN COUNTY

Crown Point Mine

SW¼ sec. 8, T. 31 N., R. 16 E.

The Crown Point mine is situated about halfway up the south wall of the cirque at the head of the valley southwest of Hart Lake. It is at an altitude of about 5,000 feet and is reached by taking the Railroad Creek trail out of Holden.

The property was discovered in either 1897 or 1898, but no reference to it is made in the literature until 1901,[10] when a deposit of molybdenite is mentioned as being worked by the Crown Point Mining Co. of Seattle. The article also reports that the development work carried out by the company consisted of about 110 feet of open cuts and 275 feet of tunneling. Again in 1902 and 1903 the mine is mentioned in Mineral Resources of the United States as having a small production. In 1903 a large crystal or cluster of molybdenite crystals weighing 300 pounds was shipped. No production, except for a small amount in 1907, is again reported until 1914, when the Aurelia Crown Mines Co. produced a small amount. Later, in 1917, there was also a small production. Then in 1933 the last work to be done at the Crown Point mine was initiated by the Acme Molybdenum Association, consisting of a minor amount of underground development.

F. W. Horton[11] gives the following excellent description of the Crown Point mine:

> The molybdenite-bearing deposit at the Crown Point mine consists in the main of a nearly horizontal vein of white vitreous quartz, which outcrops for a distance of several hundred feet on the northeast face of an almost perpendicular granite cliff at a height of 700 or 800 feet above its base. This vein dips slightly (perhaps 5° to 6°) west. On the outcrop its maximum thickness is about 3 feet, and pinches gradually to 3 or 4 inches at both ends of the outcrop. The vein also decreases rapidly in thickness as it runs back into the cliff, and in a distance of 75 to 100 feet it practically pinches out. . . .
>
> An inspection of the local topography makes it evident that the hill in which the vein occurs once extended much farther to the northwest, and that a considerable part of it has been removed by erosion to form the valley on which the present cliff faces. It is certain that the molybdenite-bearing vein extended into this eroded part, but there is no evidence from which to determine how much of the vein has been carried away.

[10] Mineral Resources of the United States, p. 266, 1901.

[11] Horton, F. W., Molybdenum; its ores and their concentration: U. S. Bur. Mines Bull. 111, pp. 79-81, 1916.

The molybdenite occurs scattered irregularly through the quartz in masses ranging in size from minute specks to pieces 4 to 5 inches in maximum diameter. In general the molybdenite is unusually well crystallized, and the deposit probably affords finer specimens of the mineral than are to be obtained from any other known occurrence. Most of the crystals have the form of flat, hexagonal pyramids, the majority of which are beautifully striated. Some of them are one-half to 1 inch high, and 4 to 5 inches in maximum diameter, and weigh one-fourth to one-third of a pound each. The contrast afforded by these lustrous black crystals on a background of clean white quartz is strikingly beautiful. . . . . A few masses of molybdenite larger than those mentioned above are found, and the company states that "some have been mined that weighed over 5 pounds," and that "one weighed 11 pounds." In general, the molybdenite does not occur in the center of the vein, but is confined to horizons extending from a line 2 to 3 inches from the center of the vein to a line the same distance [from] either wall. The accessory minerals are unimportant. Small quantities of chalcopyrite and copper carbonates derived from it occur at several places in the vein, also occasional small patches of galena and sphalerite. These minerals are, however, largely confined to occurrences along the walls or in the immediately adjoining country rock. On the whole, the quartz-vein material is remarkably free from all minerals except molybdenite. In several places along the outcrop and in the tunnels where molybdenite is exposed to the air it has altered to molybdite, and fine specimens of partly altered crystals may be obtained.

The country rock is a medium- to fine-grained, greenish-gray biotite granite in which the feldspars are kaolinized to a considerable extent. The biotite is also more or less altered and is in various stages of chloritization. According to analyses made by Zaumbrecker and Pierce, (†) of Northwestern University, the country rock does not contain molybdenum. Crook, in describing the occurrence of molybdenite at this mine, (‡) cites the absence of molybdenum in the neighboring granite as an indication that the molybdenite in the vein has not been derived by lateral secretion.

About 10 feet immediately below the vein already described and roughly parallel with it there is a second smaller quartz vein which outcrops for a short distance along the face of the cliff. The vein is only a few inches in thickness, but it is said to be richer in molybdenite than the larger vein. Little development work has been done on it, and nothing can be said of its possibilities.

Development work on the upper vein consists of two short intersecting tunnels. The larger of these, locally known as Tunnel No. 1, runs about 200 feet west and is intersected at an acute angle by Tunnel No. 4, which is about 80 feet long and runs southwest. The author's examination of the property was of necessity confined almost entirely to an inspection of the upper vein as disclosed by these two tunnels, as a heavy snowstorm, in progress at the time of his visit, rendered work along the outcrop on the face of the cliff impossible.

(†) Crook, A. R., Molybdenite at Crown Point, Washington: Geol. Soc. America Bull., vol. 15, p. 287, 1904.

(‡) Crook, A. R., op. cit., pp. 283-288.

In addition to Horton's report the following comments are of interest. The granite contains two prominent sets of joint planes; one is nearly flat and the other about vertical. The planes are not close together, so the rock breaks into large rectangular blocks. The thin shear zone that was mineralized by quartz and molybdenite is along one of the major flat-lying joint planes. This mineralization altered the granite only slightly, causing minor sericitization up to 3 inches distant from the vein. Along the face of the cliff the vein appears to have had its greatest thickness, but as work proceeded inward from the cliff the vein decreased to only a few inches and in places pinched out altogether.

From the above description it is readily apparent that though the Crown Point mine at one time undoubtedly did produce some of the finest crystals of molybdenite in the world, it is unlikely that many more will be found or that the mine will be a commercial source of molybdenum.

Robischaud Prospect

SE¼ sec. 29, T. 31 N., R. 20 E.

The Robischaud prospect on the northeast side of Lake Chelan about halfway up the lake is at the head of Safety Harbor Creek on its northeast side at an altitude of about 6,500 feet. It is best reached by taking the road from Manson to Safety Harbor Creek, a distance of about 30 miles. From the end of the road a trail leads up the east side of the creek for a distance of 5 miles to the workings. The property has been known for the past 50 years.

The mine workings consist of three adits and several open cuts. The uppermost adit and associated open cuts do not show any indication of molybdenite. The open cuts were so badly sloughed and caved that their geology could not be studied. Even though the uppermost adit is caved, the portal reveals that the adit was driven along two vertical veins 2 feet thick and about 1 foot apart striking approximately north. The veins at the portal entrance appear to be composed of fault gouge which is strongly stained by iron oxide. However, in the adit the veins apparently contain quartz, as the dump shows chunks of quartz having ramifying fractures filled with chalcopyrite and chalcocite. At first glance it is easy to mistake the chalcocite for films of molybdenite in the fractured quartz. These pieces of ore indicate that the mineralized areas occur as lenses 1 to 2 inches thick in the veins. An assay of the eastern vein at the portal showed no gold or silver.

About 75 feet east of the upper adit is an open cut showing thinly foliated metamorphic rock containing scatterings of pyrite and films of azurite and malachite, but no molybdenite. Here, an assay of a sample showed no gold, no silver, and 0.94 percent copper.

Approximately 350 feet slope distance and 200 feet vertically below the upper workings are two adits about 150 feet apart and at the same elevation. The westernmost of these two lower adits is caved. The country rock is granitic in character, being composed of fine-grained granular anhedral quartz, feldspar, and biotite. On the dump are pieces of this rock having thin quartz-filled fractures which contain scatterings of small molybdenite crystals.

The easternmost adit has been driven for 330 feet in strongly altered rock, which has the appearance of becoming pegmatitic toward the face. Some half a dozen thin eastward-striking, vertically dipping veins were intersected. The veins average about 6 inches in thickness and contain fault gouge and brecciated wall rock. About 200 feet of drifting has been done on the two veins containing molybdenite. These contain ⅛-inch-thick widely scattered lenses of molybdenite along with chalcopyrite and some pyrite. The chalcopyrite and molybdenite are not intermixed. Also, these veins have been locally silicified, particularly where they have been mineralized.

From the above, it is readily concluded that the molybdenite is far too scant at this property to be of commercial interest.

FERRY COUNTY

Meadow Creek Mine

Center sec. 25, T. 30 N., R. 32 E.

The Meadow Creek mine is located on the north bank of Meadow Creek about 3 miles west of where it flows into the Sanpoil River. It is easily reached by a good dirt road, which joins the main highway between Wilbur and Republic about 9 miles north of the Keller ferry.

The mine in 1950 was owned by Meadow Creek Mining, Inc., of Keller, Washington, which had 320 acres of unpatented ground. The president at the time of the writer's visit was Mr. D. Monroe of Spokane, Washington, and the superintendent was Mr. Wayne E. Richards, also of Spokane. There were about 1,600 feet of workings on the property, about 900 feet of which were in the Pearl adit, the remainder being distributed among shorter adits.

Geologically, the mine area consists of a light-gray hornblende-biotite granite which has been intruded by diorite and hornblende-feldspar porphyry dikes carrying scattered phenocrysts of quartz. Quartz veins up to a foot in thickness, carrying principally sparsely scattered pyrite, chalcopyrite, and molybdenite, are distributed through fractures and silicified zones in these rocks.

The Pearl adit is close to the Meadow Creek valley bottom on its north side at an altitude of about 1,950 feet. It has been driven for about 850 feet in a northwest direction in order to intersect the Blue Jay vein, which crops out about 500 feet up the hill above the creek.

This vein strikes N. 80° W., appears to dip about 65° S., and is about 2 feet thick. Within this 2-foot thickness are stringers up to 6 inches thick of chrysocolla surrounding nodules of chalcocite in a quartz gangue. In the fall of 1949 considerable bulldozing had been done on the outcrop; and from what had been uncovered, there seemed little chance of this vein extending to depth, because it could be traced for only a short distance along its strike at the surface.

Throughout the Pearl adit numerous dikes and small quartz veins have been intersected. These veins contain pyrite, chalcopyrite, and minor amounts of molybdenite as films along fractures. The most important of these quartz veins is about 2 feet thick and is known as the Jannott vein. It strikes N. 65° E. and dips 70° S. It is first intersected at 120 feet from the portal and, because of faulting, again at 165 feet. The dikes are intersected at frequent intervals and are composed of aplite, diorite, and hornblende-feldspar porphyry. The major part of the rock through which the adit has been driven is granite which has been mineralized and silicified. Pyrite is the principal mineral, though there are scatterings of chalcopyrite and molybdenite. A sample representative of the granite at 800 feet inside the Pearl adit was assayed with the following results: gold—trace; silver—0.18 ounce per ton; copper—0.05 percent; molybdenum—0.02 percent.

About 600 feet east of the Pearl adit is the King Richard adit, which is described by Pardee[⑩] as follows:

> The main working is a tunnel at an elevation of 1,900 feet, near the level of Meadow Creek, driven north 200 feet. Throughout this working the granite is moderately sheared, crushed, and cut by numerous fractures, the most prominent of which strick northeast and dip steeply northwest. Quartz veins, most of which are less than a foot in width, accompany all the prominent fractures, and films of pyrite are distributed through the granite along minor slips. In an exposure near the surface a short distance east of the tunnel the granite contains closely spaced wavy veinlets of molybdenite a quarter of an inch or less in thickness, closely associated with a N. 20° W. fault plane. The principal vein, exposed 130 feet from the portal of the tunnel, is 8 feet wide and bounded by smooth walls that strike N. 50° E. and dip 75° NW. to 90°. A drift follows it 40 feet to the northeast and shows it to be regular and persistent. The vein filling is quartz through which interlocking grains of chalcopyrite, pyrite, zinc blende, and galena are distributed in bands parallel to the walls. The sulphides are most abundant in a foot or two of the vein next to the footwall, and a sample of this portion yielded by assay 5 per cent of lead, 4.05 per cent of copper, and 27.12 ounces of silver to the ton. In addition, a small percentage of zinc was evidently present. So far as exposed, the vein shows but moderate effects of post-mineral movements. A winze is sunk a few feet below the drift, but no upraises or stopes have been made, and the dimensions of any portion of the lode that may be regarded as ore are not determined.

⑩ Pardee, J. T., Geology and mineral deposits of the Colville Indian Reservation, Washington: U. S. Geol. Survey Bull. 677, pp. 125-126, 1918.

To the west of the King Richard and about 25 feet above it start a series of workings extending up along a northwestward-trending gulch for about 1,500 feet to a place about 250 feet above Meadow Creek. The first of these workings are the two Hammond adits, Nos. 1 and 2. Both adits are about 50 feet long and driven in a northwest direction in granite. No. 2 is about 20 feet higher than No. 1. Hammond No. 1 contains a number of narrow aplite dikes and northeast-striking veins carrying pyrite and molybdenite. Hammond No. 2 at 47 feet from the portal contains a vertical 1- to 1½-inch quartz vein striking N. 65° E. and carrying pyrite and molybdenite.

About 250 feet to the northwest of and 50 feet above Hammond No. 2 are the two short Twin adits. The south one has been driven along a flat-lying fault in granite for 28 feet. The fault strikes N. 85° W. and dips 20° S. Throughout a thickness of 4 feet immediately beneath the fault on the north side of the adit are several narrow quartz veins striking N. 85° W. and dipping 70° N. These carry considerable molybdenite and some pyrite and chalcopyrite. The adjacent north adit is only 10 feet long.

About 130 feet northwest of and 60 feet above the Twin adits is the Lincoln adit. This has been driven in granite for 40 feet. It cuts a 6-inch quartz vein striking N. 75° W., dipping 20° N., and carrying abundant pyrite and a little molybdenite.

Roughly 400 feet northwest of and 75 feet higher than the Lincoln adit is the Waterloo. This adit, 225 feet long, has been driven S. 35° W.; the first 205 feet is in diorite, the last 20 feet in granite. At the contact is a quartz vein 2 feet thick along a fault striking N. 65° W. and dipping 28° N. The vein contains films of molybdenite and a little chalcopyrite and pyrite.

From consideration of the above facts, it appears that there is little chance for molybdenite to be produced from this group of workings.

KING COUNTY

Clipper Prospect

NW¼SW¼ sec. 34, T. 24 N., R. 12 E.

The principal mineralized outcrop on the patented Katie Belle claim of the Clipper prospect is located at an altitude of about 4,200 feet. It is well exposed along the bed of the gulch 1 mile northeast of Hardscrabble Creek. This outcrop can be reached by taking the Dutch Miller Gap trail for 5 miles northeast from Goldmeyer Hot Springs, ascending the Middle Fork of the Snoqualmie River to the creek which is 1 mile northeast beyond Hardscrabble Creek. This easternmost creek is then followed upstream until the outcrop is reached.

The Katie Belle claim is one of the Clipper group of claims owned by the Gilbreath family, who have incorporated as the

United Cascade Mining Co., Inc. Mr. M. F. Gilbreath of Seattle, Washington, is president. The company's holdings consist of 15 patented and 14 unpatented claims, which extend from one-fourth mile west of Hardscrabble Creek east to the J. T. claim, the west side line of which is adjacent to the Katie Belle.

The particular outcrop examined on the Katie Belle is, according to the owners, the richest in molybdenite. Unfortunately, because of an impending thunder storm, the examination had to be completed in half an hour, which was far too short a time. However, in this brief interval it could be seen that the outcrop is a dark reddish-brown to dark-brown oxidized zone striking east and having a vertical dip. This zone is in a sialic fine-grained phase of the Snoqualmie granodiorite. The zone apparently varies in thickness from 5 to 10 feet and has been hydrothermally altered by the introduction of pyrite, chalcopyrite, and molybdenite, in order of decreasing abundance. The fine-grained molybdenite occurs with bunches of euhedral pyrite in scattered narrow lenses parallel to the strike and dip of the zone. The lenses appear to be about 3 inches thick and perhaps 4 to 5 feet in diameter. The chalcopyrite is widely scattered as small grains and in tiny narrow seams. Outside of the mineralized zone, in the fine-grained sialic phase of the granodiorite, small grains of chalcopyrite are also scattered. Pyrite appears to be universally present throughout the general area as minute euhedral crystals.

Even after so brief an examination it seemed apparent that the area was capable of producing but little molybdenite and that this would have to be as a byproduct of a large copper operation should one be warranted.

Devils Canyon Prospect

SE¼ sec. 27, T. 25 N., R. 10 E.

The Devils Canyon prospect is situated at an altitude of 3,700 feet, about 1,000 feet above the east bank of the northward-flowing Cougar Creek. The property is reached by driving up the North Fork of the Snoqualmie River to Lennox Creek, and then up Lennox to Cougar Creek. From here to the prospect a trail leads south on up the ridge separating the Lennox and Cougar Creek drainages, a distance of about 1¼ miles.

The property in 1953 consisted of 4 unpatented claims held by Consolidated Molybdenum, Inc., Seattle, Washington. The president of the corporation was Mr. G. L. Hansen of 614 Yale St. N., Seattle, Washington.

The rock of the Devils Canyon area is a biotite-hornblende granodiorite. The canyon itself has been carved along parallel vertically dipping mineralized shear zones striking approximately N. 70° W. and arranged in an en échelon fashion. These mineralized shear zones parallel the regional strike of the most important jointing in this part of the Snoqualmie granodiorite. The result of this erosion has been to form an extremely steep-walled canyon, having a width between 50 and 100 feet and a general trend of about N. 40° W.

The mouth of the canyon is at an altitude of 3,700 feet. At this place there is an adit on the northeast bank of the creek. It is the only working on the property and is 159 feet long. The first 76 feet is in granodiorite. The last 83 feet is along one of the mineralized shear zones into which the canyon has been carved. As exposed underground, the zone strikes N. 70° W., dips 80° to 85° N., and is composed of altered granodiorite containing a few quartz stringers. At the west end of the shear zone the footwall is composed of a gouge seam 5 to 12 inches thick containing a dark-colored clay-like streak less than 1 inch thick composed of gouge with pyrite and molybdenite. The hanging wall is a slickensided surface along which there is in places a quartz stringer fluctuating in thickness between that of a knife blade and 1½ inches. It contains a small amount of molybdenite. The 2 feet of altered granodiorite between these planes of movement has been silicified and contains small quartz veinlets throughout, together with some pyrite and molybdenite. At the face of the adit the hanging-wall shear plane is barely visible, whereas the footwall contact has developed into a strong fault zone containing quartz and molybdenite. The shears are still about 2 feet apart at this place. A sample across the face contained 0.11 percent molybdenite. The 83 feet between the westernmost exposure of the shear in the adit and the adit's face is so completely lagged that no observations can be made. As can be determined from the description of the adit, the en échelon pattern of the joint planes is a local as well as a regional feature, having shown up within a strike length of 83 feet.

The canyon at the adit trends about N. 55° W., and for several hundred feet up the canyon the shear zone exposed in the adit may be seen intermittently. Associated with it are quartz stringers averaging about ½ inch in thickness and containing sparsely disseminated molybdenite with a few rare high-grade streaks.

About 300 feet vertically above the adit the canyon splits, the northeast split being known as Deer Gulch. Just below this gulch the granodiorite walls of the shear zone in the canyon are brecciated and healed by quartz. The quartz is of a vuggy character, as a result of which quartz crystals are common, but unfortunately they are not of commercial quality. A carbonate, possibly ankerite or siderite, and pyrite and/or pyrrhotite are also present. The shear zone in the vicinity of this brecciation does not appear to be mineralized.

About 725 feet slope distance and 400 feet vertical distance above the adit in the southwest wall of the canyon, which here strikes N. 50° W., is a mineralized zone striking N. 70° W. and dipping 87° S. This zone, which can be traced for about 200 feet along its strike, is about 3 feet thick and contains several quartz veins, twelve in one place varying from ½ inch to 8 inches in thickness. All these veins carry some molybdenite, but the greatest quantity of the mineral seems to be in a 6- to 8-inch vein just south of the zone's major plane of movement, now represented by a 2- to 3-inch gouge seam of crushed granodiorite and molybdenite. This vein is the largest of the twelve. It carries molybdenite and minor amounts of chalcopyrite and scheelite. As in the other veins, the molybdenite occurs along the vein borders in crystals from ¼ to ½ inch in diameter. There are more of the former size than the latter. A small amount of scheelite also occurs in places along with the molybdenite in the other veins. The center of the large vein is composed of slightly vuggy quartz. About 100 feet beyond this exposure the zone thins appreciably and there is a cliff causing a waterfall about 75 feet high which prevents one from going farther up the canyon.

However, in 1944 Ward Carithers, then on the staff of the Division of Mines and Geology, went up on the ridge at the head of Devils Canyon, some 2,000 feet above the adit, and attempted to go down the canyon. He was able to descend about 400 feet, beyond which place it was too steep. Nevertheless, he was able to find a shear zone, perhaps the same shear zone, 6 to 8 feet thick and containing several mineralized quartz veins. Also several quartz veins, striking N. 45° E. and dipping 20° SE., were seen that appeared to cross the shear zone. One of these contains some molybdenite, about ⅛ inch frozen on one side of a quartz vein 1 inch thick.

Below the aforementioned adit for a slope distance of about 200 feet the granodiorite is slightly fractured, but no shearing such as is exposed above is present. However, at about 200 feet slope distance and some 75 feet vertically below the adit a quartz vein striking N. 34° E. and dipping 15° N. is exposed. It is about an inch thick and in places is well mineralized with molybdenite. It can be traced about 30 feet down the dip.

From the above observations it is readily apparent that though molybdenite is widespread in the narrow quartz veins of Devils Canyon, the exposures do not indicate commercial importance.

LINCOLN COUNTY

Spokane Molybdenum Prospect

SE¼ sec. 32, T. 28 N., R. 37 E.

The Spokane Molybdenum prospect is situated at an altitude of 1,680 feet on the northeast slope of Pitney Butte. The property is best reached by driving north from Davenport on Highway 22. At 13 miles north of Davenport a right turn is made onto a good gravel road. After traveling on it for 5.3 miles, a left turn is taken onto a narrow road which is followed for about a quarter of a mile to a cabin. This cabin is headquarters for any activity at the property and in 1950 was occupied by a caretaker.

The Spokane Molybdenum prospect is owned by the Spokane Molybdenum Mines, Inc., of Spokane, Washington. Mr. Luke Bayley, who died in 1954, was president of the company at the time the property was examined. The corporation owns 4 claims, all held by location.

The rock of the area consists principally of a fine- to medium-grained granite. Within this granite are blotches of pegmatitic material and numerous quartz veins. Both the pegmatites and veins carry small amounts of scattered molybdenite. The pegmatitic material contains quartz, muscovite, molybdenite, apatite, and plagioclase which is strongly altered to sericite and calcite. Apatite occurs in unusually large euhedral crystals which fluoresce a yellow-orange color. This fluorescence was at first mistaken for that of powellite, its true nature being discovered only with the aid of the spectograph and microscope. Where the pegmatitic material contains molybdenite, the mineral occurs as platy aggregates up to 2 inches in diameter scattered rather thickly through the rock. The molybdenite appears to be essentially contemporaneous with the other minerals. None of this pegmatitic material carrying molybdenite was seen in place during the course of the investigation. However, the company does have many fine specimens.

The lowest working, at an altitude of 1,680 feet, and the next higher one, at an altitude of 1,785 feet, have both developed, to a limited extent, the same molybdenite-bearing quartz vein. In the lowest working, which has been driven southward for 258 feet and then southwestward for an additional 207 feet, the vein is intersected 55 feet southwest of the turn. Here the vein is 3 to 4 feet thick, dips 80° to the northeast, and has a strike of N. 50° W. It has been developed along its strike by drifts to the northwest and southeast. The drift to the northwest extends 20 feet and that to the southeast, 51 feet. Along the southwest wall of the northwest drift, between 12 and 20 feet from the crosscut, the vein contains sphalerite, pyrite, and a small amount of molybdenite smeared along fractures and scattered in the quartz. The rest of the vein, where exposed in the two drifts, shows a similar mineral suite, but the individual minerals are far more widely scattered.

In this same place Mr. John S. Vhay, of the U. S. Geological Survey, found considerable radioactivity. The following is quoted from his letter of February 5, 1953.

> On the west corner [of the northwest drift] there is a triangular-shaped area about 3 feet across which gives high readings on the Geiger counter. This radioactive zone is a fault breccia, about 1 foot wide at the bottom, 6 inches wide at about 5 feet up, and pinching down to narrow gouge slip in the back; the fault dips steeply northeast. In the hanging-wall side of the fault gouge at 3 to 5 feet up there is from ⅛ to ½ inch of a black soft material which seems to show the highest radioactivity.

Mr. Vhay checked the black soft material and found the radioactivity to be due to the presence of uranium rather than thorium. The stringer in which this uranium occurs contains abundant muscovite, has a general northeasterly strike, and averages about 1 inch in thickness. There are a few other places along the vein that give readings on the Geiger counter slightly above background count.

At 112 feet from the portal a drift has been driven west from the adit for 154 feet, at which point it begins to swing south for another 27 feet. The drift has been driven along thin unmineralized joints in the granite, and if it should be extended for another 40 to 50 feet, the vein described in the above paragraph would probably be intersected.

Above this lowermost working about 105 feet and to the west 340 feet is an old working from which numerous excellent specimens of molybdenite have been taken. At the time of the writer's visit during the summer of 1950 the working contained water, as it had been used as a reservoir for drilling water for the lowermost working. It has been reliably reported that this upper working intersects at a distance of 80 feet from the portal the same vein as was cut in the lowermost adit. The vein was followed to the northwest along its strike for a distance of 230 feet. It averages 3 to 4 feet in thickness and is reported to contain minor amounts of fluorite and molybdenite as scattered crystals through the quartz or in bunches associated with muscovite. The bunches of molybdenite are apparently more common near the hanging wall, but were found generally scattered through the quartz. However, much of the quartz is reported to be barren. The vein can be traced on the surface for several hundred feet to the northwest. It averages about 2 feet in thickness and is as much as 4 feet thick in places. For the most part it is barren, but some pyrite and a few specks of molybdenite can be seen. The strike of the vein averages about N. 30° W. and the dip about 70° E.

Mr. Bayley showed the writer many fine specimens of molybdenite exhibiting a pegmatitic occurrence which apparently came from the upper working. It is conceivable that the vein is appreciably richer in this upper working than it is on the surface immediately above.

About a quarter of a mile south of the lowermost working previously described and about 500 feet higher are the oldest workings on the property. The uppermost of these is directly below a triangulation station of the U. S. Geological Survey. Here a south-striking quartz vein in the granite has been opened by a 15-foot adit, having in front of it a 15-foot open cut. The quartz vein is 3 feet thick at the portal, widens to 6 feet at the face, and is greatly fractured. Both its east and west granite contacts are planes of movement, and two other planes of movement are visible within the quartz body. The quartz is barren except for a few spots of molybdenite associated with muscovite and for smears of molybdenite in the planes of movement along the east and west contacts. The contact zones vary in thickness between 2 and 6 inches. Close to the working on the east is an andesite dike.

Directly north and about 80 feet below this work is a 250-foot adit driven S. 10° W. along a thin shear dipping about 80° W. An andesite dike forms the footwall. The shear contains intermittent lenticular bodies of quartz along it, varying in thickness from ¼ inch to 6 inches. There are several spots having concentrations of molybdenite, but the quartz on the whole is barren. However, the molybdenite does occur quite persistently smeared along the shear. A branch and crosscut from the main adit starting about 170 feet from the portal and running a short distance to the southeast and east, respectively, intersected two small quartz veins, parallel to the thin main shear, containing minor scatterings of pyrite, chalcopyrite, molybdenite, and muscovite.

There did not appear to be any direct connection between the quartz vein in the adit that is just below the triangulation station and the shear with intermittent quartz which is 80 feet below it.

OKANOGAN COUNTY

Bi-Metallic Molydenum Deposit

NW¼ sec. 26, T. 39 N., R. 29 E.

The Bi-Metallic Molybdenum deposit is situated on the forested north slope of the northeast shoulder of Bi-Metallic Mountain. The mountain proper has an altitude of 4,950 feet, and the shoulder is 150 feet lower. The workings on the property extend from the top of the shoulder on down the slope for 630 feet, at which place the principal or upper (Moly) adit is located at an altitude of 4,580 feet. A lower adit, said to be about 300 feet long, that is located about 1,100 feet to the north and 500 feet lower than the upper one, is now completely abandoned and inaccessible. No sign of molybdenite or other evidence of mineralization is to be seen on its dump.

The property is easily reached from Tonasket, approximately 21 miles to the southwest, by means of a good gravel road through Havillah to Vincent's ranch, which is about 3 miles to the northeast of this village. From the ranch a 1½-mile wagon road leads southeast down across a small creek along the foot of the northeast shoulder and thence swings southwest to climb the shoulder all the way to the upper adit. Unfortunately, this road is accessible only during the summer months.

Four patented claims make up the Bi-Metallic group, which is owned by John B. Stanton, 1815 Meridian Avenue, South Pasadena, California, and was originally worked for copper.

The area in the immediate vicinity of the Bi-Metallic workings is along the northern margin of the Colville batholith. Here a granite

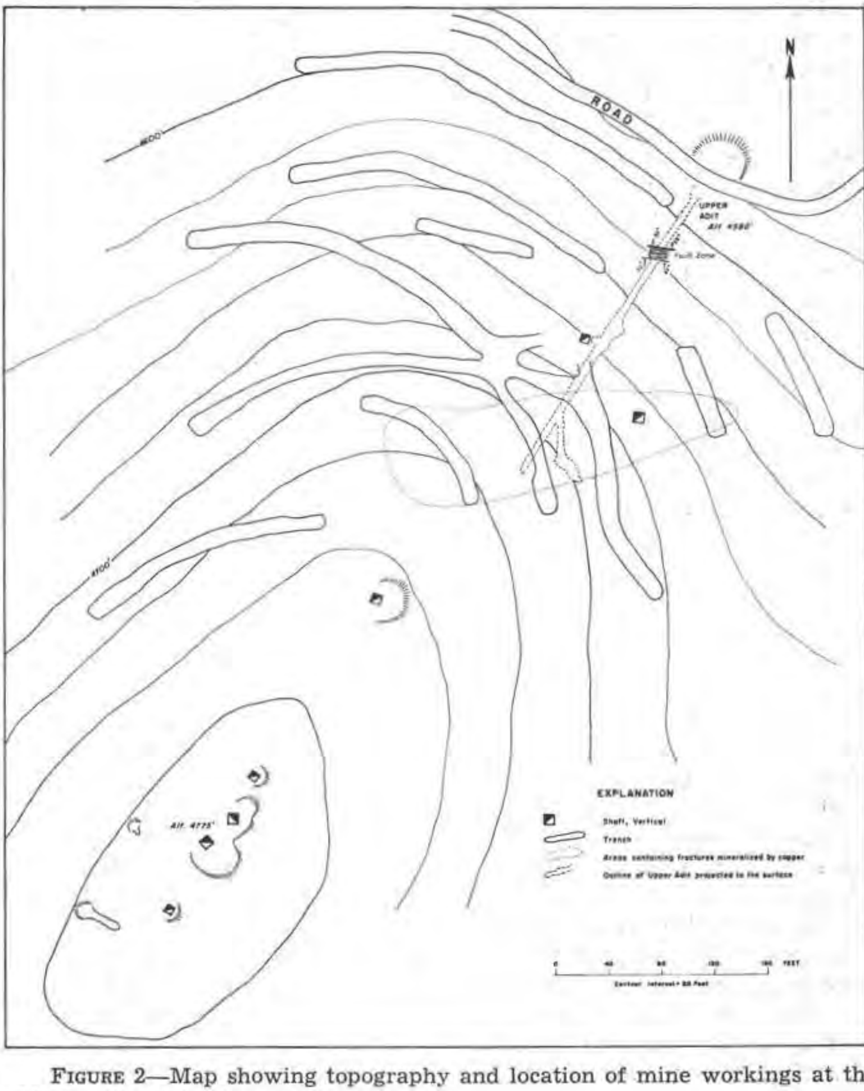

FIGURE 2—Map showing topography and location of mine workings at the Bi-Metallic Molybdenum property.

porphyry is in irregular contact with arkosic and argillaceous beds of the Anarchist series of Paleozoic age. These sedimentary rocks strike northeast and dip 12° to 20° to the northwest, and are best exposed about 400 feet east of the portal of the upper adit and throughout a small area to the southwest to a point about 200 feet south of the adit portal. A specimen collected 400 feet east of the portal shows the rock, there, to be a gray argillite. Microscopically, it is composed of quartz, orthoclase, and plagioclase fragments, angular to subangular and ranging in size from 0.015 to 0.05 mm. The groundmass has a brownish cast and contains clay minerals, carbonates, chloride, sericite, and shreds of chalcedony; all this material is extremely fine grained. The ratio of groundmass to fragments is about 3 to 1. From this location the rock changes gradually, almost imperceptibly, to a metamorphosed arkose along its strike to the southwest. Microscopically, the arkose consists of rounded to subrounded quartz and orthoclase fragments ranging in size from 0.15 to 0.30 mm. The orthoclase has a very dusty appearance caused by the development of sericite and clay minerals. The fragments are in a clear recrystallized matrix, which has a good mosaic pattern representing a quartz-feldspar intergrowth. The individual granules of the matrix average about 0.015 mm., and minor amounts of chlorite are contained in it. Also present through the matrix are scatterings of fine grains of euhedral magnetite and pyrite. The ratio of groundmass to fragments is about 1 to 1.

The top of the northeast shoulder of Bi-Metallic Mountain is some 350 feet farther to the southwest, at an altitude of 4,775 feet (see fig. 2). Here there are five shafts, 50 to 60 feet deep, and four of them are within 50 feet of one another. These were probably dug during the early work at the property. The prospecting is reported to have been done about 1890, and in 1918 several tons of copper-gold ore are said to have been shipped from one of the shafts. From this period until June 1945, when the U. S. Bureau of Mines[19] investigated the property, apparently no work was done. To quote from the report by Storch:

> The Bureau of Mines completed 2,200 linear feet of angledozer trenching in 11 trenches. The trenches were 12 to 20 feet wide and 2 to 7 feet deep on the uphill side. All pertinent details of surface and mine workings were surveyed with a transit and mapped. Twenty-seven channel samples were taken from mineralized sections of the trenches and the underground workings. These samples were analyzed for molybdenum, copper, gold, and silver by the Bureau of Mines laboratories in Reno, Nev.

A sample, taken from the central one of the five shafts at the top of the hill where a small amount of green copper carbonate is visible, contained 0.64 percent Cu, less than 0.01 percent Mo, and a trace of Au and Ag. The rock, here, has innumerable textural variations caused by the occurrence of irregular and contorted streaks of dark-green ferromagnesians and light feldspars in varying proportions for any given unit area. The percentage of quartz is low. Megascopically, the rock might be described as being dioritic in composition, and it undoubtedly represents a contact metamorphic

[19] Storch, R. H., Preliminary exploration of Bi-Metallic molybdenum deposit, Okanogan County, Washington: U. S. Bur. Mines Rept. Inv. 3932, 1946.

zone. About N. 25° E., a distance of 300 feet from the shafts, is the southern edge of a small area of steep-dipping fractures that was trenched and sampled by the U. S. Bureau of Mines. Here the rock types are similar to those in the vicinity of the shafts on top of the hill, but to the north of this area they apparently grade into a granite porphyry. At the southern edge of the area a zone containing copper mineralization, which had been localized along thin fractures, is about 260 feet long and about 70 feet wide, striking east. Eight Bureau of Mines samples, cut only across individual fractures, represent an average thickness of 1.9 feet and assay 0.92 percent Cu, 0.01 percent Mo, and a trace of Au and Ag. The remainder of the Bureau of Mines surface sampling, in that part of their trenching which extended for 200 feet to the north of the copper mineralization, revealed nothing of significance: Copper averaged about 0.10 percent; molybdenum, about 0.01 percent; and gold and silver, a trace each. A specimen of the granite porphyry characteristic of the trenched area was collected at the top of the raise connecting the upper adit to the surface. A microscopic examination of this specimen showed that it contains broken and fractured dusty euhedral phenocrysts of sericitized Na-oligoclase ranging in size from 0.6 mm. to 1.8 mm. thick and 1.2 to 3.0 mm. long. The other phenocrysts were evidently pyroxene, as is indicated by the chloritic pseudomorphs. The groundmass and some of the filling of the fractures in the phenocrysts consist of a fine-grained micro-pegmatitic intergrowth of quartz and orthoclase. Throughout the groundmass, but always in close association with the plagioclase phenocrysts, and filling such parts of their fractures as are not occupied by the micro-pegmatitic intergrowth, are clusters of carbonate, chlorite, clinozoisite, and some epidote. In certain places these clusters may represent pyroxene phenocrysts. Small masses of pyrite, magnetite, and hematite are not uncommon.

At the time of the examination of the property by the writer, the trenches were too badly caved for effective mapping of geology. Consequently, only the outlines of the trenches have been shown on figure 2 in order to indicate geographical relationships at the property. The fracturing in the trenches appears, from Storch's observation, to have no particular significance in terms of ore, and shows no relationship to the fracture pattern of the molybdenum zone in the upper adit. A Bureau of Mines microscopist made a petrographic study of oxidized samples from these surface trenches to determine whether the absence of molybdenite at the surface might be the result of leaching and migration of a primary ore. According to this work, quoting directly from Storch:[16]

> The specimens contained numerous specks of limonite pseudomorphic after pyrite. No secondary molybdenum minerals were found in any of the samples. There were many vugs which were commonly empty or filled with iron oxide and clay. Since molybdenite occurs in a

[16] Storch, R. H., op. cit., p. 3.

very wide variety of crystal forms varying from massive through granular to hexagonal prisms, the shape of the vugs is no reliable basis for an opinion on the possible former presence of molybdenite. The inference, based solely on a complete lack of positive evidence, is that the specimens did not contain molybdenum at any time.

The upper adit (see fig. 3), whose portal is 600 feet N. 35° E. from the shaft group at the top of the northeast shoulder of Bi-Metallic Mountain, strikes S. 28° W. and extends into the hill for 245 feet. The rock at the portal is typical of that throughout the adit, the only differences being those brought about through hydrothermal alteration of varying degrees of intensity. A thin section of this rock at the portal shows it to be probably granulated and recrystallized granite porphyry. The principal constituents are feldspar and chlorite. The feldspar consists of angular to subrounded fragments of both orthoclase and oligoclase, the boundaries between fragments being characterized by suture texture. The fragments average about 0.2 mm. in diameter and vary in size from a finely crushed powder up to 0.6 mm. The recrystallized feldspathic mass was apparently fractured after the initial recrystallization, because the chlorite occupies thin interweaving fractures. The feldspars are somewhat dusted by sericite and clay minerals and contain inclusions of scattered minute apatite crystals. Magnetite grains are also present throughout the slide.

For the first 45 feet of the adit there are no significant features and the rock shows little or no hydrothermal alteration. At 45 feet is a fault zone with a horizontal thickness of 10 feet. The hanging wall of this zone dips gently to the north and contains a much thicker gouge than the steeper footwall. The entire zone seems to indicate that the fault is a thrust, and that horizontally the hanging wall moved west with respect to the footwall. The vertical component of movement, however, is the stronger. The hanging wall on the east side of the adit dips 25° N., and on the west side it dips 30° N. The weaker footwall fracture dips 65° N. on the east side and 50° N. on the west. The fault zone itself is composed of crushed rock that has been bleached and contains some sericite and clay minerals. Beyond this zone is 28 feet of rock showing relatively slight alteration, beyond which at a weak fracture a molybdenite-bearing zone starts. As can be seen from the plan map of the upper adit level (fig. 3), the mineralized zone may extend west from the weak cross fracture to the northward projection of the 60° eastward-dipping fault and then south along the hanging wall of this fault. At the southernmost point of mineralization a small amount of malachite, probably derived from chalcopyrite, occurs with the molybdenite. The locations of the principal concentrations of molybdenite are shown on the map by dotted shading. Accompanying the molybdenite are small widely scattered areas of fine-grained pyrite. Except for the barren and weakly altered area which starts just beyond the

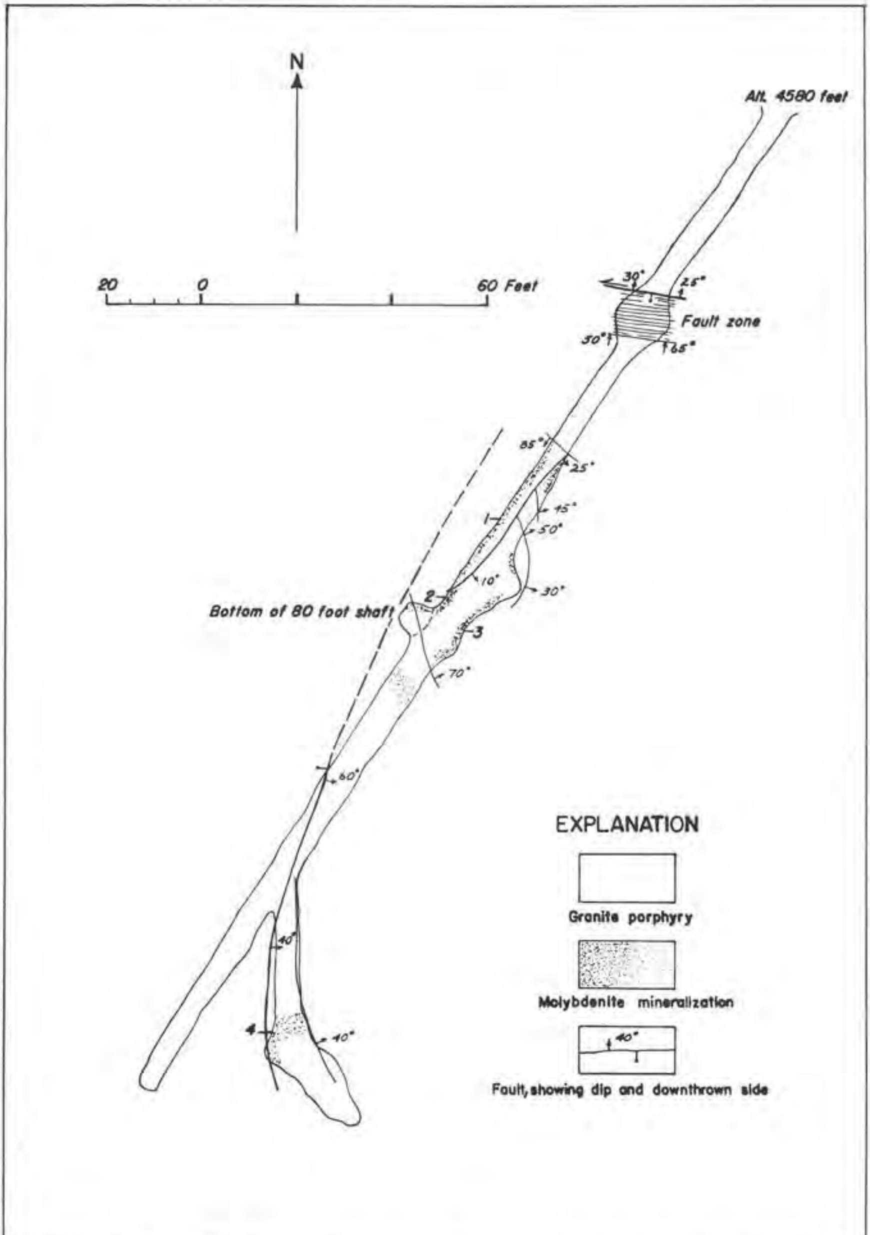

FIGURE 3.—Geologic plan of the upper adit at the Bi-Metallic Molybdenum property.

shaft and extends to the southernmost area of molybdenite concentration, the ore is well distributed through the zone. This zone is a locale of intense movement and alteration, as evidenced by much brecciation, fracturing, and bleaching of the rock. The principal fractures are shown on the map; besides these, however, are numerous short irregular fractures with both steep and gentle dips. At the northeast end of the mineralized zone, flat-lying fractures are staggered one above the other with no continuity and a highly variable strike and dip. Also, flat-lying faults are visible in the lower 20 feet of the shaft. The southernmost area of mineralization in the upper adit is between the stronger fault to the west and a weaker fault to the east. This weaker fault is not the true hanging wall of the mineralized zone, and there is good indication that the zone extends on to the east. The molybdenite is intimately associated with brecciation and fracturing. Thin-section study shows that the principal mineralogical difference between the mineralized zone and the wall rock is a bleaching effect accompanied by increased development of sericite and clay minerals. Also, as the intensity of hydrothermal alteration increased there was limited formation of green biotite instead of chlorite. Under the microscope the molybdenite appears along fractures, as irregular blotches in the feldspar (predominantly orthoclase), and as a vug filling. Fractures now healed by quartz can be seen crosscutting the molybdenite mineralization.

The U. S. Bureau of Mines took four samples in the mineralized zone, and their location is shown by the numerals 1, 2, 3, and 4 on the map. Traces only of gold and silver were found by the assays, and the following table gives the results for molybdenum and copper:

TABLE NO. 1

Sample no.	Length of sample (ft.)	% Cu	% Mo
1	6.0	0.07	2.20
2	5.0	0.05	3.87
3	4.5	0.03	3.76
4	4.0	0.32	2.59
Weighted av.........	4.9	0.11	3.07

The following are the facts, taken from the above description, that have to be accounted for in any analysis of ore possibilities at the Bi-Metallic property:

1. The presence of molybdenum in amounts equal to 0.01 percent or less as shown by the sampling of the surface trenching.
2. Copper and minor amounts of silver in thin fractures appearing to be the only metals of possible economic importance in the surface trenching, and in only one particular area. Directly beneath this area and about 40 feet to the north the

mineralization in the upper adit was confined to molybdenum. However, along with the molybdenum, at sample location 4, which is directly beneath the copper mineralization, is a small percentage of copper, 0.32 percent.

3. The presence of the strong and bleached flat-lying and north-dipping fault zone, and the fact that its trace was not intersected by the Bureau of Mines trenching.
4. The significance of the curving north-striking, east-dipping fault intersecting the upper adit 180 feet from the portal.
5. The hydrothermal alteration and crush effects in the upper adit mineralized zone.

If the trace of the major thrust fault based on measured strike and dip is drawn out on a map showing the Bureau of Mines trenching, at no place west of the adit would the trace be intersected; however, on the east side of the adit the trace should have been intersected by the trenches, but was not. On the other hand, a reduction in angle of dip of as little as 3° would move the trace out beyond the trenches. Thus the trenching did not prove or disprove the extended presence of the fault. If this fault has any extent and hence significance from the standpoint of ore, it should be found to intersect the shaft which connects the surface to the upper adit. The shaft is not accessible without some retimbering, and unfortunately the Bureau of Mines did not map the geology of the shaft at the time the trenching was done. Thus the only evidence for the extension of the fault to the shaft is the strength of the fault zone itself and the fact that the bottom of this shaft is in a zone of hydrothermally altered granulated and recrystallized granite porphyry, whereas the top of the shaft is in comparatively fresh undisturbed granite porphyry. Neither of these criteria, perhaps, can be considered positive. However, accepting the extension of the fault as the most logical assumption and its age as pre-mineral because of the hydrothermal alteration along it and immediately beneath it, a possible explanation for the distribution of the copper and molybdenum values may be proposed.

In 1946 Mackay[10] advanced the hypothesis that some elements require a more perfect barrier than others to impede their progress and that these differences are reconciled with the general position of the metals in the hydrothermal series. This hypothesis is based on the fact that the penetrability of elements through a semipermeable barrier depends upon the lack of affinity of the element for water, which in turn seems to depend upon several factors, such as molecular size, ionic size, and valence. Those elements having smallest ionic size and highest valence have the least penetrability. However, the whole question of the relative penetrability of the elements is

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[10] Mackay, Robert A., The control of impounding structures on ore deposition: Econ. Geology, vol. 41, pp. 13-46, 1946.

highly complex and not well understood. The reader is referred to Mackay for further discussion.

From the standpoint of the Bi-Metallic mine and on the basis of Mackay's hypothesis, it seems plausible to assume that copper would have greater penetrability than molybdenum because the former has a larger ionic radius and lower valence. Thus the distribution of copper and molybdenum values at the Bi-Metallic can be accounted for. According to this hypothesis and the physical conditions present at the Bi-Metallic, the molybdenite mineralization took place beneath the major flat-lying thrust and along the east, or hanging-wall side of the curving north-striking and east-dipping fault. In this way the predominantly molybdenite mineralization would have been caught in a wedge-shaped trap, while the weak copper mineralization would have been able to proceed on through, and from the distribution as indicated by assays this appears to be a reasonable explanation. If this explanation is correct, it is probable that there would be a certain amount of mushrooming of the mineralization beneath the semipermeable barrier; thus causing the deposit to be richest at the apex of the wedge and decreasing in richness with depth. Whether or not the deposit would become noncommercial with depth cannot be accurately predicted.

If the fault is found to be post-mineral instead of pre-mineral, the ore body will have been cut off and the upper part probably eroded. The lower part would extend to depth with a more even tenor of mineralization, because of the lack of the effect of a semipermeable barrier. Again, if the projection of the flat-lying thrust fault cannot be found in the shaft connecting the upper adit to the surface, the distribution of copper-molybdenum values may be due to a zoning. Should this be true, there would be no mushrooming effect, and the mineralization would probably continue to depth with a steadier tenor of grade.

Consequently it is important from the standpoint of economics to determine the status of the flat-lying thrust. Aside from the thrust fault, any exploration program should first consider some east and west crosscutting in order to determine accurately the walls of the deposit, and further drifting to the south in order to discover its extension, because at the present time nothing is known about the limits of the mineralized zone. Any work at depth should be based on this preliminary work in the upper adit.

Storch[7] in his report includes the following three paragraphs and a table on ore-dressing tests which were run on ore from the upper adit.

> A small sample of the molybdenum ore from the Moly adit was given a preliminary test by the U. S. Bureau of Mines metallurgical testing laboratories at Salt Lake City, Utah. The ore was crushed and sampled,

[7] Storch, R. H., op. cit., p. 4.

and a head sample was prepared for assay. Owing to the small amount of sample, only preliminary ore-dressing was attempted. Results indicated a reasonably easy treatment by flotation.

A final figure on the grade of concentrate and the possible recovery could not be estimated without further testwork. The results of the preliminary test are summarized in table 2. The grade and recovery given in the table may be considered much lower than could be expected from a full-size operation. It should be noted that the copper, lead, and iron content of the concentrates is low. Assays show both molybdenite and molybdite.

The combined concentrate and middling recovery in this test was 67.1 percent. It is probable that satisfactory results can be obtained by flotation of ore of this grade. Further ore-dressing work would be required to confirm this.

TABLE 2. SUMMARIZED RESULTS OF METALLURGICAL TESTS

Product	Weight	Weight, percent	Assay, percent				Recovery, percent			
			MoS_2	MoO_3	Fe	Cu	Pb	MoS_2	MoO_3	Fe
Heads	....	....	2.0	0.44	1.4	.....	....	....	....	....
Flot. conc.	23g	2.32	48.9	.68	1.6	0.1	0.1	55.3	4.0	5.5
Flot. mid.	16g	1.61	14.8	.95	3.8	.15	.3	11.8	4.0	8.9
Flot. tall.	952	96.07	.7	.36	.6	.1	.1	32.9	92.0	85.6
Calc. heads	991	100.00	2.04	.375	.673	.....	....	....	....	....

From all the above data and conclusions it would appear that the Bi-Metallic property has, as well as the highest grade molybdenum ore in the state, a favorable geologic environment and is thus worthy of further attention.

In further support of the above conclusions the following data on the Questa, New Mexico operation of the Molybdenum Corporation of America are pertinent. In 1951 this operation and the Climax operation were the only two mines in the United States being operated for their molybdenite content alone. The mining and milling methods at the Questa deposit are described in two information circulars of the U. S. Bureau of Mines, Nos. 6514 and 6551 respectively. In these circulars, from which the following information is taken, J. B. Carman, manager of the Questa operation, describes the mining and milling methods for a 10-month period during 1930.

The mineralization at the Questa deposit took place in fissure veins near the contact of a small stock of soda-potash alaskite porphyry intruded into pre-Cambrian gneiss and schist. The molybdenite-bearing quartz veins, containing some pyrite and scatterings of biotite, fluorite, rhodochrosite, and calcite are distributed very irregularly in east-west fracture zones, which are sometimes several hundred feet wide. The veins consist of groups or sets of closely spaced, branching and interfingering fractures that are often separated from other vein systems in the same shear zone by many feet of barren rock. The fracture zones are much longer as well as wider than the mineralized veins found within them. The dip of the veins ranges from 20° to 90° and averages about 60°. Also, it may change greatly or reverse itself. The veins are commonly 200 to 500 feet long and extend down their dip about one-third as much as their horizontal length. The width of mineralization ranges from a fraction of an inch to 6 feet; sometimes the walls of the vein may be 10 feet apart, but in such instances the ore is confined to thin streaks close to the walls, with sericitized country rock between. More usually the molybdenite veins are quartz and the molybdenite is distributed as follows: On both sides of the vein there are slickensides of almost pure molybdenite, varying from paper-thin seams to 1 to 2 inches in thickness. In the quartz there are scattered molybdenite crystals or a network of thin blades of molybdenite. For the whole mine the average width of material taken as ore is probably between 12 and 18 inches. Some relatively large stopes have been worked on veins averaging 4 feet in thickness. Ore of exceptional purity can be stoped profitably when as thin as 2 inches, and is commonly mined from veins not over 6 inches thick.

Taken as a whole, the ore bodies are of small size and irregular distribution, which makes them difficult to find and expensive to explore and develop. Because of the extreme irregularity of the ore, it can not be projected, and diamond drilling and long-hole drilling are untrustworthy. The mining is done largely by means of horizontal cut-and-fill stoping, plus some open stoping where the dips are gentle and the walls strong. The average cost of mining a ton of ore in this deposit for the 10-month period was $10.77, and the cost of concentrating a ton of ore during this time was given as $2.69. The ore was ground to -150 mesh and concentrated by flotation at the rate of 40 tons per day. The heads averaged 5.08 percent molybdenite and the concentrates 71.13 percent molybdenite. During that period 11,239 tons of ore were treated and 673 tons of concentrate were produced. Also during this time the price of molybdenite concentrate varied from 35 to 55 cents per pound of contained molybdenite. From these data it can readily be computed that a good margin of profit was realized from this Questa operation. The mine operated continuously on this scale until 1947, when added facilities expanded the mill to 240 tons per day capacity, and through increased mill efficiency the old tailings could be treated as well as primary ore. In 1930 the tailings were averaging about 0.68 percent molybdenite. This loss was due to extremely fine grained molybdenite remaining attached to gangue fragments, and it was felt at the time that finer crushing was impractical.

All these Questa mine data, even when extrapolated from 1930, indicate that a molybdenum deposit such as the Bi-Metallic, with an ore possibly averaging 4 percent molybdenite, can be worked in a small way and a good profit secured, if a suitable potential reserve can be indicated, say 100,000 tons.

DUTCH JOHN, SHERWOOD, LODGE PROPERTIES[18]

Sec. 2, T. 31 N., R. 22 E.

The Dutch John, Sherwood, and Lodge properties are treated here as one geologic unit. They are on the southwestward-trending ridge in sec. 2, (31-22E), about 4½ miles southeast of Carlton and about 1 mile south of Texas Creek. In 1943 H. E. Seneff of Kirkland controlled the Dutch John property of 80 acres in the W½SW¼ sec. 2. S. J. Sherwood of Twisp and W. L. Lodge of Soap Lake controlled the two 80's to the northeast.

There is a sparse growth of timber on the properties, but practically no water for mining operations.

The major part of the development work consists of numerous open cuts. The underground workings consist of two short adits and a 12-foot shaft located on top of the ridge 420 feet S. 20° E. from the Dutch John cabin. One of the adits is at the northeast corner of the Dutch John cabin and has been driven southeastward for 85 feet. The other adit, about 50 feet farther northeast, has been driven southeastward for 35 feet and is now caved.

The top of the ridge and the upper part of the northwest slope is made up of a series of thin-bedded mica schists, argillites, limestones, and quartzites. To the northwest of the ridge is a large intrusive body of diorite. Although the exact contact between the diorite and the metasedimentary rocks is not exposed, the approximate contact (within 50 feet) can be traced for about 1,500 feet at the north end of the ridge. At the southern end of the ridge in the vicinity of the Dutch John cabin the nearest exposure of diorite is several hundred feet to the west. Narrow aplite and pegmatite dikes probably related to the diorite have been injected into and between the metasedimentary beds and in places produce a lit-par-lit effect.

The detailed structure is complex, but in general the metasedimentary beds appear to lie near the nose on the northwest limb of an anticline pitching to the northeast. For about 300 feet south of the cabin the beds strike about N. 85° E. and dip from 15° to 35° NW., with the dips progressively increasing from southeast to northwest. On top of the ridge south of the cabin the beds strike about N. 50° W. and dip from 15° to 20° NE. This general strike and dip continues along the ridge top to its northeast end. About 3,000 feet N. 60° E. of the cabin the beds strike about N. 60° E. and dip 30° SE. Minor discrepancies in the major structure are not uncommon, but occur most frequently near the contact between the metasedimentary beds and the diorite. The thinly laminated beds are slightly crenulated, and there has been the development of numerous small drag folds whose structure indicates they are on the northwest limb near the nose of a major anticline pitching northeast.

[18] Culver, H. E. and Broughton, W. A., Tungsten resources of Washington: Washington Div. Geology Bull. 34, pp. 51-52, 1945.

Several of the limestone beds have been altered to garnet (grossularite) with smaller amounts of epidote, calcite, molybdenite, scheelite, magnetite, pyrite, and chalcopyrite. There are at least ten of these garnetiferous beds exposed over an area 3,000 feet long and 1,000 feet wide. They vary from 1 to 9 feet in thickness and average about 3 feet. Just south of the cabin a garnet bed averaging about 4 feet in thickness covers an area of about 800 square yards on the surface. A 2- to 4-foot garnet bed is exposed for a distance of 100 feet, 300 feet S. 20° W. from the cabin. A 3- to 9-foot garnet bed 340 feet S. 20° E. from the cabin is exposed for a total distance of 850 feet. Several smaller garnet beds are exposed in this same general area. About 2,000 feet due east of the cabin are several small exposures of 1- to 5-foot garnet beds. About 3,000 feet N. 60° E. of the cabin are several 2- to 3-foot garnet beds exposed over an area of 280 square yards.

The garnet beds have probably resulted from alteration and replacement of certain lime beds by solutions and gases given off from the diorite mass at the time of its intrusion. Chemical composition and permeability probably determined which of the calcareous beds were replaced. The molybdenite and chalcopyrite do not occur in sufficient quantities to constitute ore of molybdenum and copper, but there are small areas several feet in diameter that would make good molybdenum ore. Much of the magnetite occurs as bladed crystals, up to 1 inch across, showing well-developed parting. Frequently several magnetite crystals are arranged in radial pattern. The scheelite occurs scattered through the garnet rocks, and there is considerable variation in the scheelite content of various beds as well as in different parts of the same bed. The scheelite crystals range from minute specks to as much as a quarter of an inch across. The average scheelite content of the garnet beds is estimated to be less than a quarter of one percent. Considerable powellite, resulting from the oxidation of the molybdenite and scheelite, has formed in the garnet beds.

No molybdenum or tungsten ore has been produced from these properties.

Horseshoe Basin Prospect

Center sec. 11, T. 40 N., R. 23 E.

The Horseshoe Basin molybdenum prospect, owned by Paul Loudon, Robert Curtis, and Loy McDaniels of Loomis, Washington, is situated at about 7,000 feet in altitude on the south slope of Arnold Peak, approximately ⅔ mile south of the Canadian border. This general area is known as Horseshoe Basin and is at the source of Horseshoe Creek flowing to the west and at the source of a branch of the North Fork of Toats Coulee trending to the east. This area is best reached by horseback from Four Point Camp, a distance of about 12 miles. Four Point Camp is accessible by automobile from

Loomis and is located a short distance west of the Middle Fork of Toats Coulee.

The prospect was originally staked by Fred Manweller in about 1926 and then abandoned. It was restaked in July 1951 by Messrs. Loudon, Curtis, and McDaniels, who have staked out two claims, Horseshoe Basin Nos. 1 and 2. The area covered by the claims is one of fine-grained biotite-hornblende schists with some intercalated coarse-grained quartz diorite gneiss. Both rock types have been invaded by quartz-feldspar pegmatites containing scattered pyrite and molybdenite. The schist area as a unit is interpreted by Daly[⑲] to be a roof pendant which has been left after the successive intrusions of the Similkameen granodiorite and the Cathedral biotite granite. The pendant extends to the northwest and west across Arnold Peak for about 2 miles and is about half a mile wide.

At the original discovery or main prospect outcrop the principal rock type, microscopically, is a black fine-grained biotite-hornblende schist having about 60 percent Ca-andesine which contains scattered minute inclusions of apatite. Fine magnetite crystals are scattered throughout the slide. Also a small amount of quartz, perhaps 2 percent, is present. The andesine varies in size from 0.05 mm. to 0.15 mm., whereas the hornblende and biotite laths are up to 0.3 mm. in length. The schist is probably a metamorphosed basic extrusive rock. It strikes N. 70° W. and dips 60° to the northeast. Approximately parallel with the schist and intercalated with it is a coarse-grained quartz diorite gneiss, containing biotite, hornblende, quartz, and andesine. The andesine has been partly altered, and minute shreds of sericite are scattered throughout the interior of the grains. The borders of the andesine grains show the effect of cataclasis. The thin section indicates a moderate development of chlorite and a small amount of zoisite replacing the hornblende. The grain size exclusive of cataclasis varies from 0.3 mm. to 3 mm. and averages about 2 mm. In both rock types the individual mineral grains are invariably anhedral.

The pegmatite at the prospect's principal outcrop has an interesting configuration, which is duplicated at several places within the schist and gneiss zone. The direction of strike and dip of the pegmatite dike is essentially parallel to the schistosity, but at the southeast end the pegmatite appears to have the form of a steeply plunging pipe and cuts across the schistosity. The vein part of the pegmatite is 4 feet thick and then widens to the southeast into a circular pipe-like mass about 10 feet in diameter plunging to the east at about 80 degrees. The greatest concentration of molybdenite and pyrite is in this pipe-like area, but minor amounts are scattered through the pegmatitic vein. The pegmatite is principally quartz; however, a

[⑲] Daly, R. A., Geology of the North American Cordillera at the 49th parallel: Canada Geol. Survey Mem. 38, p. 432, 1912.

substantial quantity of orthoclase is also present, and fine graphic intergrowths are common. Numerous inclusions of schist and gneiss, which apparently have been but little altered by the pegmatite, can be seen. The molybdenite and pyrite occur as scattered patches in the pegmatite and evidently crystallized directly from the pegmatitic material, as no structural controls within the pegmatite are evident. The molybdenite patches vary in diameter from an eighth of an inch up to an inch and average about half an inch. The patches of pyrite are rarely an eighth of an inch, and usually much smaller. A small amount of yellow ferrimolybdite was visible at the outcrop as the principal oxidation product. Very little limonite had formed. As no systematic sampling has been attempted, no report as to grade is possible; however, rather close scrutiny indicates that no minerals of commercial interest other than the molybdenite are present. Some time was spent in searching for scheelite, but none was found. Nevertheless it is by no means impossible that either scheelite or molybdenite might be found in other parts of the roof-pendant area.

About 300 feet to the northwest along the strike from the main prospect cut or original discovery is another similar pegmatite mass. Since the writer's visit to this general area, it has been reported that dynamite shots in the second pegmatite have revealed molybdenite to about the same extent that it is present at the original discovery.

Too little exploratory work has been done in this area to evaluate with any confidence its possibilities for the production of molybdenite.

Sheep Mountain Prospects

SW¼ sec. 8, T. 40 N., R. 20 E.
NW¼ sec. 17, T. 40 N., R. 20 E.

The Sheep Mountain prospects are in two groups, the Barker Brown group and the Dodd group. The first of these is located on the south slope of Sheep Mountain at an altitude of about 7,400 feet. The other group is about 100 feet higher and to the north. Also, part of this group is on the southeast slope of the northeast ridge of Sheep Mountain at about 7,200 feet in altitude. The mountain is best reached by driving from Winthrop to the end of the road on Eightmile Creek. From here a good horse trail leads north over Billy Goat Pass to Sheep Mountain, a distance of about 17 miles.

Sheep Mountain, as contrasted with the sharp rugged peaks of the Cascade Mountains, has a rounded summit and is on a high open rolling plateau, which has a general altitude of about 6,500 to 7,500 feet, in the extreme north central part of the state between the Cascade Mountains and the Okanogan Valley. Sheep Mountain has an altitude slightly over 8,200 feet and is composed of granodiorite containing scattered quartz lenses and a few dikes of trachyte porphyry.

To the best of the writer's knowledge, in 1950 the Barker Brown group was claimed by no one. The principal open cut exposes a quartz lens 2 to 3 feet thick striking N. 35° W. and dipping vertically. The quartz is rusty and contains pyrite scattered through it. Apparently the open cut had originally exposed the quartz lens along its strike for about 50 feet, but in 1950 it was sloughed too badly to see the quartz actually in place. Above and north of the open cut a short distance is a milky quartz lens about a foot thick containing an irregular inclusion of granodiorite and small amounts of pyrite.

The Dodd group, as far as is known to the writer, is held by possessory title by Leslie and Oren Dodd and associates. As described in the opening paragraph, the group is divided into two parts. That part which is on the south slope of Sheep Mountain and north of the Barker Brown group has been opened by a trench connecting at its north end with a short adit. This opening exposes an irregular quartz mass 3 to 4 feet thick striking approximately northwest and dipping vertically. This mass contains irregular hydrothermally altered inclusions of granodiorite, in the vicinity of which are imbedded crystals of pyrite and, rarely, fine-grained molybdenite. The two sulfides are also found in the vicinity of the walls. This gathering of the sulfides along contacts may possibly be due to the neutralizing effect of the wall rocks on an acid mineralizing solution.

That part of the Dodd group on the southeast slope of the northeast ridge of Sheep Mountain has been opened by one adit and four open cuts. The lowest open cut is just above the north shore of Sheep Lake, in a cirque basin on the east side of Sheep Mountain. This cut exposes a small mass of white to rusty quartz containing a few scattered euhedral pyrite crystals, though they have been largely weathered out. The wall rock is nowhere exposed.

The adit and the other three cuts which represent the major development on Sheep Mountain are about a quarter of a mile north of Sheep Lake. The lowest working, the adit, is at the toe of the steep southeast slope of the northeast ridge. The adit is about 50 feet in length and has been driven along a flat-lying vuggy quartz lens about 2 feet thick, striking N. 30° W. and dipping about 20° to 25° SW. Ramifying stringers from this lens extend into the granodiorite country rock, and there are inclusions of the country rock in the quartz. Some pyrite is present sparsely scattered in the quartz, but no molybdenite.

About 20 feet higher and up dip from the adit is an open cut exposing this same quartz lens.

About 100 feet above the last-mentioned cut is a large quartz dump, exhibiting a few pieces of quartz containing inclusions of country rock and associated fine-grained molybdenite.

Slightly above and east of the quartz dump is exposed a quartz lens 4 to 5 feet thick, striking N. 30° W. and dipping 20° to 25° SW. The quartz is rusty and contains pyrite. Also present are numerous vugs within which have developed excellent quartz crystals, but not sufficiently large or perfect to be of commercial value. Splitting from the main quartz mass are stringers of quartz, one of which is about a foot thick. Also, throughout the country rock in the vicinity of the lenses are fine thin quartz veinlets having the same strike and dip as the lenses. These veinlets are vuggy and carry scattered pyrite.

The country rock is a coarse- to medium-grained granodiorite and contains inclusions of fine-grained biotite-rich quartz feldspar rock.

From the above description it can readily be ascertained that the Sheep Mountain prospects do not have possibilities as commercial producers of molybdenite.

GEOLOGY OF THE STARR MOLYBDENUM MINE, OKANOGAN COUNTY, WASHINGTON[20]

By

S. C. Creasey[21]

[20] Publication by the Washington State Division of Mines and Geology authorized by the Director, U. S. Geological Survey.

[21] Geologist, U. S. Geological Survey.

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ILLUSTRATIONS

GEOLOGY OF THE STARR MOLYBDENUM MINE, OKANOGAN COUNTY, WASHINGTON

By S. C. Creasey

ABSTRACT

The Starr molybdenum mine, Okanogan County, Wash., is about 5 airline miles west of Tonasket in the north-central part of the State. The mineralized zone has been explored to a depth of 250 feet by means of three adit levels, one sublevel, and a raise which connects two of the adits and the sublevel. In all, there are about 2,700 feet of underground workings. The mine has neither machinery nor a developed water supply adequate for any work other than a small exploratory program.

The Starr molybdenum mine is estimated to contain about 800,000 tons of indicated and inferred ore having a grade of about 0.30 percent MoS_2. Inadequate assay data in the lower levels prevent more accurate calculation of reserves.

The country rock is a biotite-hornblende granodiorite. The mineralized zone is brecciated and stands nearly vertical in the granodiorite. The brecciation may have resulted from jointing and local intense fracturing along intersecting faults.

The granodiorite in the breccia zone is more or less intensely silicified from place to place. Quartz veins and irregular stringers and blebs of vein quartz are common throughout the zone. Molybdenite and pyrite occur as disseminated flakes and grains in the silicified granodiorite. At least two and possibly three generations of molybdenite are indicated by megascopic observations; probably all are part of one period of mineralization.

The grade of the deposit has discouraged its exploitation at the price of molybdenite that has prevailed in recent years. However, under any program to determine accurately the molybdenum reserves of the United States, the deposit merits accurate sampling and outlining of the mineralized zone on the upper levels, and probably also diamond drilling below the No. 3 adit level to determine the depth and grade of mineralization.

INTRODUCTION

The Starr molybdenum mine is in sec. 8, T. 37 N., R. 26 E., Willamette base line and meridian, in north-central Washington. It is about 5 airline miles west of Tonasket, Wash., in the Okanogan River valley, and is 25 miles south of the Canadian border. The property is accessible by 10.3 miles of dirt and gravel country road and 1.1 miles of very poor dirt road over private property. Tonasket, on the Okanogan Branch of the Great Northern Railway, is the nearest railroad station.

In general, the property is inaccessible from December to April because of heavy snowfalls. The private road is not passable for heavy trucking or for any automotive equipment when the ground is wet or snow-covered, and the country dirt roads probably are locally impassable for heavy trucks during spring thaws.

A large supply of water is not available at the property. When the writer examined the deposit in August, the underground workings yielded several gallons of water per minute, and the water level in the only well on the property was about 10 feet below the surface. There probably is sufficient water for a small exploration program, but not enough for intensive development work. Ample stands of pine and fir are available locally for timbering in the mine.

The deposit is within the area of the U. S. Geological Survey Chopaka quadrangle. It lies on the southeast flank of Aeneas Mountain, between Aeneas Creek and Horse Springs Coulee. The mountains are locally steep, with as much as 40° slope, but in the area as a whole the topography is much more subdued. In the small area studied, the topography appeared to reflect the influence of the fracture and fault structures in the granodiorite country rock.

The Starr molybdenum mine was first examined by the U. S. Geological Survey in August 1942, at the request of the War Production Board. The subsequent work by the writer was part of the general program to obtain detailed information on occurrence, grade, and reserves of molybdenum deposits in the United States.

The U. S. Bureau of Mines made a brief examination of the property in July 1943. Their assay data are included in the assay maps accompanying this report.

Published information on the Starr mine and the geology of the adjacent areas is meager. Patty and Glover (1921) described the deposit briefly in 1920. Waters and Krauskopf (1941), as part of their study from 1935 to 1937 of the Colville batholith and adjacent areas, mapped the area on a scale of 1 inch to 2 miles.

From August 1 to 28, 1944, the writer mapped the underground and surface geology for the U. S. Geological Survey. The plan maps of the No. 1, 2, and 3 adits are based on transit surveys, and the upper workings are tied to the No. 3 adit by a transit-stadia traverse. The plan map of the 202 XCE on the 200 sublevel is based on a Brunton compass-tape survey; the plan of the 203 XCW, which is inaccessible, was obtained from Roy A. Clark, 421 West Roy Street, Seattle, Wash. The surface was mapped by plane table and alidade.

HISTORY AND DEVELOPMENT

The original discovery of the Starr deposit was made in 1915 by Andrew Starr, who at that time staked five claims. In recent years the property was transferred to Andrew Starr's son, Wilbur Starr; all the claims were dropped except the Silver Tip, which contains all the known mineralized area. Wilbur Starr resides in Horse Springs Coulee, and his mail address is Tonasket, Wash.

In 1928 the property was explored by the Molybdenum Corporation of America, 500 Fifth Avenue, New York, but it was not operated because of the low grade of ore. The Molybdenum Corporation's development work is represented by all the accessible workings of the No. 3 adit, all but a small part of the 200 sublevel, and all of the No. 1 and No. 2 adits except for a 12-foot winze in the No. 2 adit. A total of about 2,600 feet of drifts, crosscuts, and raises was driven by this company.

In 1935 and 1936 the Titanium Alloy Manufacturing Co., Niagara Falls and New York, N. Y., held an option on the property; they released the property on January 1, 1937. Their work is represented by a raise and winze in the No. 3 adit, a small amount of drifting in the No. 2 adit and 200 sublevel, and a winze—subsequently filled—in the No. 2 adit. In addition, they excavated 15,000 cubic feet of rock from 12 surface pits and trenches and 1 shaft.

According to information received from Wilbur Starr, in 1939 Carl Lundstrom sorted the dumps and shipped about 3,000 tons of ore containing over 1 percent MoS_2 to his mill at Nighthawk, Wash.

GEOLOGY

The Starr mine and the surface areas mapped are entirely within an isolated intrusive mass of biotite-hornblende granodiorite (pl. 1) that is about 2 miles long and 1 mile wide. The rock is composed of about 70 percent feldspar, 15 percent quartz, and 15 percent biotite and hornblende combined; biotite is about twice as abundant as hornblende. Sphene appears to be the most common accessory mineral. Here and there are masses of rock containing phenocrysts of orthoclase. Aplite and lamprophyre dikes in the granodiorite are common but not plentiful. According to Waters and Krauskopf (1941), the rock is the Similkameen biotite-hornblende granodiorite of Mesozoic age. It is entirely surrounded by the middle member of Daly's (1913) Anarchist series (late Paleozoic), which is composed of metasediments—chiefly quartzites, metaconglomerates, graywacke, and a few lenses of metamorphosed limestones.

Structure.—The principal structures in the granodiorite are faults and related fractures, at least one joint set, and the breccia zones in which the ore is localized. In general, the major faults can be divided into two groups: (1) those that strike N. 10°-30° E., and (2) those that strike N. 10°-30° W. Little is known about the movement on these faults other than that most of them appear to have a vertical component. Because of the monolithic character of the rock and its uniformity, the physiography is the best clue to the location of the faults. The step-like benches in the topography suggest the direction of relative movement on the faults, and the straight-line canyons, which locally contain depressions or sag ponds, indicate the trace on the surface. Where it was possible to establish the existence of the faults by underground observations, the physiography appeared to express correctly the fault structures in the granodiorite. The fault that cuts the No. 3 adit near the 6000 E. coordinate appears to be a reverse fault, but the fault that traverses the 700 E. coordinate (pl. 1) is thought to be a normal fault.

The extent of brecciation along the faults is represented by the mineralized breccia in the Starr mine and by the breccia zone at the southeast corner of the area mapped. The origin of the breccia zones is not known; however, with contemporaneous activity of closely spaced faults having different strikes and dips, local zones of brecciation are to be expected. Branch faults and fractures from the main faults are common, as exemplified by the fracture pattern in the No. 3 adit between the 306 DS and the 309 XCNE shown on plate 5.

Fractures parallel in strike and dip to the major faults are very common over the entire area mapped. They are most numerous and best developed near the faults, hence they are thought to be due to the same stresses that caused the faulting. Apparently, they were open to some extent, as shown by the dikes and quartz stringers commonly found in them. Joints striking N. 10°-40° E. and dipping 25°-40° NW., and joints striking N. 70°-80° E. and dipping to the southeast, usually at a high angle, are common. These joints may form a joint set, although the area mapped was too small to show this positively.

Although the controls that localized the breccia zones are not known, fault intersections offer a plausible explanation. Except for the northwest end which appears to pitch to the southeast, the Starr mine breccia zone is nearly vertical. The 203 XCW (pl. 6), which might afford more definite information, is not accessible. Premineral structural features of the breccia zone are largely obliterated by the partial to complete replacement of the granodiorite by quartz and, to a lesser extent, by sulfides. Some information is available from the post-mineral fractures, which appear to have followed previously mineralized breaks. In general, the fractures found in the breccia zone are thought to be essentially like those in adjacent areas, but as fracturing within the zone was much more intense than outside it, the shattering and movement shifted the angular blocks sufficiently to leave open spaces and channels for access of the mineralizing solutions. The size and attitude of a breccia zone thus formed would depend on such variable factors as the attitude of the faults, irregularities in strike and dip of the faults, and the direction and amount of movement along them.

Many examples of fractured vein quartz and smeared or slickensided molybdenite along fault veins indicate appreciable post-mineral movement along mineralized fractures and faults. The stream gravel faulted against the breccia zone in the portal of the No. 2 adit is conclusive evidence of recent faulting in the area. The amount of post-mineral movement on the faults is thought to be small, because the breccia zone is not noticeably offset. However, because of the uniformity of the rocks, small horizontal and even large vertical displacements would not be readily recognized.

MINERALIZATION

The size and shape of the mineralized zone is known only roughly. In plan view, it is an attenuated ellipse ranging from 300 to 440 feet in length and from 50 to 130 feet in width. The shape in cross section is only partly known because the top is eroded and the bottom unexposed; however, the walls are nearly vertical from the surface to the No. 3 adit, a depth averaging about 240 feet. The northwest end of the deposit appears to pitch a few degrees to the southeast. There is no information on the size and shape of the mineralized zone below the No. 3 adit, although the elliptical shape in plan continues at least to this level.

The silica that was introduced into the mineralized zone caused silification of the granodiorite and formed veins, stringers, and blebs of quartz that have filled irregular fractures. Sericitic alteration is usually weak, but locally it is more intense. Pyrite, molybdenite, and possibly a trace of chalcopyrite and arsenopyrite occur as disseminations and fracture coatings in all the above-mentioned modes of occurrence of the quartz and silicified rock. A few large crystals of scheelite were found in the mineralized zone in the No. 3 adit and in the 1-foot quartz vein in the No. 1 and No. 2 adits.

The area of visible molybdenite mineralization on the surface is not as widespread as the boundary of the zone indicated, which is based on assay data (pl. 2). Trenches 8 and 9 and pit 5, all of which are in the mineralized zone according to assay data, appear barren of sulfide mineralization and of all but a trace of rock alteration, as does the area northeast from trench 9 to the crest of the small ridge. Most of the molybdenite in the surface excavations occurs as disseminations; the fracture coatings of molybdenite, so apparent in the underground workings, are rarely seen or nonexistent. In the zones of massive silification or in vein quartz where the molybdenite is not exposed to oxidizing agents, the molybdenite is stable under surface conditions. The open fractures and fractured quartz veins, where molybdenite and pyrite could readily be expected, are barren or partially filled with a soft yellow-brown material containing chiefly iron oxide. A sample of this material from the No. 2 trench assayed 0.06 percent molybdite. It is thought that the molybdenite originally present in these fractures has been oxidized to molybdite and largely carried away, possibly by mechanical washing or in colloidal solution, or both. A sample of similar brownish-yellow material that is being deposited on the walls of the 310 XCN in the No. 3

adit by descending waters assayed 0.08 percent molybdite. Whether it is being deposited chemically or mechanically is not known.

The No. 1 adit is entirely within the mineralized zone and contains the highest over-all average molybdenum content of any of the workings. The weighted average is 0.51 percent MoS_2. The silicified granodiorite is blocky from many irregular, intersecting fractures. Irregular quartz stringers and blebs are common, and several pyrite-molybdenite quartz veins are present. The molybdenite occurs principally in fractures in both the quartz and the altered granodiorite; less molybdenite is disseminated in the rock and quartz. The quartz veins are fractured locally and probably occupy old lines of structural weakness.

The No. 2 adit is also within the mineralized and brecciated zone. The mineralization and rock alteration here are similar in appearance to those in the No. 1 adit, although the grade, as determined by assays, is lower. Near the last crosscut, the Titanium Alloy Manufacturing Co. sank a 12-foot winze on a strongly mineralized zone 4 feet wide. They reported the best sample assayed 1.91 percent MoS_2 and the poorest assayed 0.81 percent MoS_2. The winze has been filled in.

The 202 XCE on the 200 sublevel lies within the mineralized zone. The granodiorite is more massive and more intensely silicified than in either the No. 1 or 2 adits. Most of the molybdenite in the western half of the crosscut is disseminated as flakes in the silicified country rock, which is a fine-grained, dense, siliceous mass with little or no resemblance to the original granodiorite. This rock appears to contain less molybdenite, owing to the absence of the molybdenite-coated fractures common elsewhere in the mine. The extent of the mineralization in the 203 XCW and the 201 raise between the 200 sublevel and the No. 2 adit is not known. The raise is accessible by rope only.

The No. 3 adit is the only working that has cut the boundary of the mineralized zone in several places, thereby offering more information on the characteristics of the brecciated and mineralized zone. The intensity of the silicification in the No. 3 adit decreases sharply outward from the mineralized zone, but does not entirely disappear for as much as 200 feet from the molybdenite-mineralized zone. As the mineralized zone is approached, the first indication of rock alteration is a dull appearance, with the outlines of the individual mineral grains becoming indistinct or hazy. Still closer to the mineralized zone small stringers and blebs of quartz appear, the rock becomes duller, and the ferromagnesian minerals begin to disappear. Finally, at the boundary of the mineralized zone, the amount of introduced silica forming silicified rock, quartz veins, and blebs increases to such an extent that the original textures and structures of the granodiorite are commonly all but obliterated. Pyrite mineralization, especially along fractures and small faults, is more widespread than molybdenite mineralization. The partly altered granodiorite, slightly mineralized with pyrite, forms a halo of variable thickness around the molybdenite zone of mineralization.

It is thought that many of the pre-mineral fractures and joints that served as solution channels were obliterated by the silicification or "healed" by vein quartz. If this is true, the intensity of the original brecciation is unknown.

Although the entire mineralized zone is silicified, the intensity of the silicification varies greatly from place to place. Local zones are altered to fine-grained, dense masses composed almost entirely of quartz. Such zones are found in the No. 1 shaft, No. 7 pit and in the 200 sublevel and No. 3 adit. There are all gradations between the quartz veins and silicification, but many of the quartz veins are distinct and commonly cut the silicified rock, indicating an age difference. Sericitization, in general, appears to be widespread in the mineralized zone, but it is much weaker than the silicification. The amount of sericite is difficult to estimate because it is finely divided in the rock. The strongest sericitization is in the breccia zone in the southeast corner of the area mapped (pl. 1).

The pyrite and molybdenite in the mineralized zone occur as disseminated grains and flakes in the silicified granodiorite and quartz veins, as fracture coatings, and as stringers or seams enclosed in the altered rock and quartz veins.

The outline of the mineralized zone in the No. 3 adit is determined largely by assay data. The 309 XCNE and the 310 XCN are mineralized and brecciated, but the molybdenum content is too low to include this area in the mineralized zone. If this area constitutes a low-grade block in the mineralized zone, the boundary of the mineralized zone would lie farther north and northwest, conforming more closely to the surface outline.

Without the aid of microscopic and polished-section laboratory investigations, the sequence of mineralization cannot be accurately determined. From megascopic observations, the pyrite and molybdenite appear to be essentially contemporaneous. They commonly occur together, but each is found independent of the other. After the silicification of the granodiorite and the associated pyrite and molybdenite mineralization, there has been at least one and possibly two periods of refracturing and further deposition of quartz, pyrite, and molybdenite, both contemporaneously and independently. Scheelite is thought to have been formed late in the sequence of mineralization. The first period of refracturing and mineralization is suggested by distinct molybdenite-pyrite quartz veins cutting the silicified rock, and the second period by molybdenite in fractures along the margins and central planes of these quartz veins.

OXIDATION AND LEACHING

Although the exact depth of oxidation is not known, the bottom of the oxidized zone is between the No. 2 adit level and the 200 sublevel. The surface, No. 1 adit level, and, to a lesser extent, the No. 2 adit level all show typical features of partial oxidation. The rock is much softer, owing to a partial breakdown of the feldspars to clay minerals. Pyrite near the surface is largely altered to iron oxide, leaving an iron-stained boxwork.

As stated previously, the molybdenite in the open fractures and in the fractured quartz veins has been oxidized and to a great extent removed. Whether the molybdenum was removed in solution or as hydrous ferric molybdate in colloidal suspension is not definitely known, but assay data do suggest that most of it was dissipated in the rocks immediately underlying, and, to a lesser extent, in the rocks adjacent to the source.

Table 1 shows the relative amount of molybdenite and molybdite in channel samples taken from the surface and from all the levels except the No. 3 adit.

TABLE 1

Location	Sample length feet	MoS_2 %	$Fe_2O_3 \cdot 3MoO_3 \cdot 7\frac{1}{2}H_2O$ %	Total % MoS_2 (Converted)
No. 3 trench	10	0.08	0.16	0.19
No. 6 trench	10	0.18	0.39	0.44
No. 1 adit........	10	0.26	0.37	0.51
No. 2 adit	10	0.26	0.031	0.28
200 sublevel	8	0.17	0.004	0.173
200 sublevel	8	0.15	0.023	0.165

In these samples molybdite was identified only megascopically from the No. 6 trench and from the No. 1 adit, and in both of these samples the quantity of molybdite seen was greatly subordinate to molybdenite. Apparently, the molybdite becomes intimately associated with iron oxide and other secondary products to such an extent that as much as 0.25 percent cannot be recognized megascopically.

It is noteworthy that the mineralized zone on the surface and in the No. 1 adit has a much higher total molybdenum content than in the No. 2 adit, 200 sublevel, or the No. 3 adit. Whether or not the higher molybdenum content is due to a slight enrichment by molybdite is not known. If the molybdenum near the surface in the form of molybdite is not indigenous, the over-all estimate of 0.30 percent MoS_2 for the grade of the deposit would be higher than the grade of the sulfide zone.

The amount of molybdite in the oxidized zone is roughly indicated by the three samples from the surface and the No. 1 adit. Although more samples would be necessary to determine the extent, and to obtain a quantitative estimate of the amount of molybdite in the oxidized zone, the samples do suggest that possibly as much as 50 percent of the molybdenum content, from the surface to a depth of 30 feet, is in the form of molybdite. Molybdite, being a hydrous ferric molybdate, is not recovered in the flotation-type treatment plant usually used to recover molybdenite.

RESERVES AND GRADE

The deposit is estimated to contain 800,000 tons of indicated and inferred ore averaging about 0.30 percent of equivalent MoS_2. Assays below the No. 3 adit are not sufficient in number to permit more accurate classification. The individual assays are given on the assay maps in the envelope in the back of this report.

In calculating the ore reserves, the outline of the mineralized zone on the surface was assumed to extend half the distance from the surface to the No. 3 adit, and the outline in the No. 3 adit to extend half the distance to the surface. The outline in the No. 3 adit was used in calculating ore reserves below the adit level. Twelve cubic feet of mineralized rock was assumed to weigh a ton.

The generalized size and shape of the deposit is known. However, because the No. 1 and No. 2 adits and the 200 sublevel all are entirely within the mineralized zone, the exact locations of the boundaries of the mineralized zone between the surface and the No. 3 adit are not known. Fortunately, the shape is similar on the surface and in the No. 3 adit, and probably no large error in tonnage is introduced by projecting the respective outlines to a median plane equidistant between the two.

In the writer's opinion, the assay data do not permit any of the reserves to be classified as measured ore. The silicified granodiorite in the No. 3 adit and the 200 sublevel is too tough and hard to hand-sample accurately. For this reason the grade of ore of these two levels, as determined from the available assays, is questionable. Although the assays from the No. 1 and No. 2 adits are probably reliable, the part of the mineralized zone explored by these workings at their respective levels is so small as to leave considerable chance for error in assigning the grade of these workings to the upper half or third of the deposit. It is not known whether the sites for the surface excavations were chosen at random or on the strength of the mineralization in the outcrop. If the latter is true, the surface assay data would be misleading and would require adjustment.

In 10 character samples taken by John J. Collins of the U. S. Geological Survey and assayed by the Geological Survey laboratory, from 0.01 to 0.04 percent arsenic was present in nearly all of the samples, but no tungsten was found by spectroscopic analysis down to 0.03 percent.

RECOMMENDATIONS

The estimated grade, 0.30 percent MoS_2, in this deposit has discouraged mining. However, the deposit is a strategic reserve of molybdenum, and under any program to accurately determine the molybdenum reserves of the country for possible future use, the Starr mine merits further consideration. It is not the writer's intention to outline an exploration program; however, certain general aims are probably worth mentioning. The inaccessible workings, which include the 314, 311, and 201 raises and the 203 CXW on the 200 sublevel, should be reopened, mapped, and sampled. The 200 sublevel and the No. 3 adit should be sampled by pneumatic chippers. A diamond-drilling program should include short holes from the No. 2 adit and 200 sublevel to further sample and outline the mineralized zone between the No. 3 adit level and the surface. The possibility of extension of the mineralized zone north and northwest of the 310 XCN should be determined. Possibly this could be accomplished by rehabilitating and sampling the 203 XCW on the 200 sublevel. If not, diamond drilling from the 310 XCN might be done.

The extent and grade of the mineralization below the No. 3 adit level should be determined, preferably by diamond drilling. Additional trenching and sampling of the mineralized zone on the surface undoubtedly would be advisable to determine whether or not the present excavations were located on high-grade outcrops.

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Waters, A. C., and Krauskopf, K., 1941. Protoclastic border of the Colville Batholith: Geol. Soc. America Bull., vol. 52, pp. 1355-1418.*

* End of U. S. Geological Survey report by S. C. Creasey.

SNOHOMISH COUNTY

Copper Lake Area

Sec. 4, T. 29 N., R. 10 E.

A molybdenum occurrence was reported at the head of Copper Lake in the Sultan Basin area by F. E. Wing of Tacoma, Washington. An investigation of the occurrence showed that the molybdenite occurs very sparsely scattered in a few narrow (one-fourth-inch) quartz veinlets in quartz diorite. No molybdenite was seen in place, but it could be observed on the sides of the quartz diorite talus blocks where they had split along joints. Thus, this occurrence has doubtful commercial possibilities.

Glacier Peak Copper Property

Center sec. 10, T. 31 N., R. 15 E.

The Glacier Peak Copper property is located on the southwest slope of Plummer Mountain at an altitude of 5,500 feet on the north side of Miners Creek. This property is best reached by taking the road up the Suiattle River. This road ends about 1 mile below Milk Creek; from there a trail leads 13 miles to the mine workings. These consist of six adits, one 450 feet long, the others from 100 to 150 feet long.

In 1951 the property was under option from the Glacier Peak Mining and Smelting Co. to the Hanna Coal and Ore Corporation of Cleveland, Ohio. It consists of 32 claims and a millsite, 12 of which are patented.

The following brief description of the property is provided through the courtesy of the Hanna Corporation.

Since 1917 a total of 27,885 feet of diamond drilling has been done at the property. During the period 1917-18 American Metals did 1,984 feet of drilling. Through the years 1937-42 the M. A. Hanna Co. drilled 19,079 feet of holes. In 1943 the International Smelting and Refining Co. did 6,822 feet of diamond drilling. Since then no further activity has taken place at the property. Quoting from the Hanna Corporation's brief report:

> The predominant rocks of the area are granodiorite and gneiss which have been intruded by dikes and irregular bodies of quartz-monzonite porphyry, aplite, and andesite. The mineralized zone at Glacier Peak is a brecciated granodiorite pipe roughly circular in shape and approximately 600 feet in diameter. The breccia pipe has been intruded by porphyry, aplite, and andesite, and all these rock types contain the sulphide mineralization with the exception of the andesite.
>
> Abundant white, glassy quartz; coarse, white mica; iron oxides; chalcopyrite; pyrrhotite; pyrite; and molybdenite form the cementing material of the breccia. Minor amounts of arsenopyrite, galena, sphalerite, tetrahedite, tourmaline, and carbonate were also found in drill

cores. Some zoning of the mineralization is evident, but actual distribution of sulphides throughout the breccia pipe is unpredictable.

From diamond drilling, trenching, and tunneling, a substantial tonnage of low-grade, high-cost material has been proven. Copper grade is comparable to the porphyry coppers with small amounts of gold, silver, and molybdenum recoverable as byproducts. The MoS_2 content is approximately 0.12%.

Other reliable investigators have suggested a different hypothesis as to the geology of the deposit. Briefly, this differs from that of the Hanna Co. in that the brecciated granodiorite pipe is considered to be rather a zone of closely spaced joints that have been filled by quartz veinlets mineralized by chalcopyrite and molybdenite. Otherwise, the geological ideas are in essential agreement. It has also been indicated that the chalcopyrite and molybdenite replace the ferromagnesian minerals in the wall rock to a small extent and that the copper is distributed uniformly and the molybdenum erratically. It is reported that there are two similar ore bodies about 1,000 feet apart. Adjacent to the main ore body is a massive, generally barren quartz plug, which contains a few high-grade zones. The main ore body is at least 600 feet by 350 feet in cross section and 400 feet deep. The northeast ore body is thought to be similar but smaller. It is egg-shaped in cross section and is known to extend to a depth of 500 feet, but the lower boundary is not known.

Reportedly more than a thousand assays have been made at the property and these indicated that there are several million tons of ore containing about 1 percent copper and 0.1 percent molybdenite, or about twice this estimated quantity assuming a cut-off grade of 0.67 percent copper and 0.03 percent molybdenite. Besides these figures, average values of 0.0022 oz. per ton for gold and 0.283 oz. per ton for silver have been determined.

From the above data it is quite apparent that molybdenite's only importance in connection with this deposit is as a possible byproduct.

Golden Eagle Prospect[69]

Sec. 7, T. 28 N., R. 10 E. and sec. 12, T. 28 N., R. 9 E.

The Golden Eagle property of 10 unpatented claims is owned by the Washington Molybdenum Co. of which Robert Anthony, of Seattle, is president and E. L. DeSilets is secretary [1954]. It is in sec. 7, (28-10E) and sec. 12, (28-9E), near the head of the South Fork of the Sultan River. A trail leads up this stream to a small cabin on the property. The mineral exposures are southwest of this cabin on a steep hillside, between altitudes of 3,000 and 3,400 feet, where a 2- to 15-foot fracture zone strikes N. 81° E. and dips 80° SE. through

[69] Carithers, Ward, and Guard, A. K., Geology and ore deposits of the Sultan Basin, Snohomish County, Washington: Washington Div. Mines and Geology Bull. 36, p. 75, 1945.

quartz diorite. An open cut in a gully, at an altitude of 3,150 feet, shows a gouge zone 6 to 30 inches thick which contains scattered flakes of molybdenite. Other narrow fractures, parallel to the gouge seam, contain thin veinlets of quartz, molybdenite, and a little chalcopyrite. Some of these veinlets have slickensided walls on which molybdenite is smeared, indicating that minor movement occurred along them after this sulphide was deposited. Pegmatite float, occurring in the gully near this open cut, contains the best molybdenite specimens found on the property, and some crystals measured as much as three-quarters of an inch in diameter. Other open cuts and natural exposures of the vein occur up the gully for about 600 feet, and these show thin veinlets of quartz, molybdenite, and chalcopyrite, and a 6- to 24-inch gouge seam enclosed within the fracture zone. At an altitude of about 3,350 feet, a flat-lying pegmatite lens 3 feet thick is exposed on one side of the gully. It contains a very small amount of chalcopyrite and scheelite but no molybdenite.

St. Theresa Prospect[69]

Secs. 1 and 12, T. 28 N., R. 9 E.

The St. Theresa property of 10 unpatented claims is in secs. 1 and 12, (28-9E), on the steep hillside northeast of the South Fork of the Sultan River about 5 miles above its confluence with the North Fork. A trail leading up the South Fork crosses the southern part of the property. The claims are held by the Washington Molybdenum Co. of which Robert Anthony, of Seattle, is president and E. L. DeSilets is secretary [1954]. The mineral exposures on the property are in a steep gully that trends southwest along a series of fractures through quartz diorite. The fractures are approximately 5 feet apart and strike about N. 52° E. and dip about 60° SE. These fractures vary from the thickness of a knife blade to about 1 or 2 inches and, in places, are well mineralized by molybdenite together with some quartz, chalcopyrite, and carbonates of calcium and iron. They are widely distributed through the wall rock, and some of them are remarkably persistent, being exposed over lengths of more than 100 feet.

STEVENS COUNTY

American Prospect

SE¼SW¼ sec. 16, T. 38 N., R. 39 E.

The American prospect is located about one-fourth mile N. 54° E. of Phalen Lake at an altitude of about 2,500 feet. It is reached by driving to the north end of Phalen Lake and going across country

[69] Carithers, Ward, and Guard, A. K., Geology and ore deposits of the Sultan Basin, Snohomish County, Washington: Washington Div. Mines and Geology Bull. 36, pp. 74-75, 1945.

a short distance east to the prospect. In the fall of 1950 the property was open for leasing from the State.

The prospect is situated about 25 feet east of a northward-striking granite-slate contact. The slate, which lies to the west, is black and contains considerable quartz. It strikes N. 30° E. and dips 65° E. The granite is well jointed, there being three prominent sets; two sets strike east, one of these having a vertical dip, the other a 45° dip to the south; and the third set strikes about N. 10° E. and dips 10° to the east. The quartz vein, which is vuggy and very sparsely mineralized by molybdenite and pyrite, follows the flat-lying set. The vein's thickness varies between ¼ inch and 5 feet and has been traced for about 100 feet. On the south it pinches out, and on the north it is covered with debris. Other similar quartz veins observed in the area are barren. The prospect has been developed by three open cuts 20 to 30 feet east of the granite-slate contact.

From these observations it seems clear that the possibility of any commercial production of molybdenite from this property is extremely doubtful.

Deer Trail Monitor Property

NW¼NW¼ sec. 24, T. 30 N., R. 37 E.

The Deer Trail Monitor mine is located at an altitude of 3,400 feet on the west slope of Adams Mountain, 4½ miles east of Fruitland. It is best reached by going east from Fruitland on the main road and taking the first turn to the north. This road, which swerves to the east in a short distance, is followed for 3 miles to the Spaulding road, which runs north. The first road turning east from the Spaulding road leads to the mine.

The property, abandoned in 1954, was formerly owned and operated by the late J. Richard Brown of Spokane.

The country rocks in the vicinity of the mine workings are, from west to east, hornblende-biotite granite, greenish-gray to cream-colored limestone, black argillite, and quartzite which is considered to be part of the Addy quartzite of early Cambrian age. The sedimentary rocks have steep dips of approximately 80° to the west and strike N. 20° to 30° E.

The principal working is an eastward-trending adit, which has been driven as a crosscut. At 216 feet from the portal the granite-limestone contact was intersected. Here the limestone is a greenish color for several feet from the contact. The adit then passes through 205 feet of gray- to cream-colored limestone. About 30 feet past the granite-limestone contact a slip, striking N. 30° E. and dipping 80° E., crosses the adit. It contains about 8 inches of iron-stained gouge. At 432 feet from the portal a fault is intersected which strikes N. 30° E. and dips 80° E. This fault has been followed for 120 feet, from which place a crosscut has been driven southeast for 160 feet.

The first 30 feet is in limestone, then a fault is intersected, and black and brown argillite is exposed. The last 50 feet of this crosscut is quite sheared and is caved at the face. About 40 feet northeast of the end of the main crosscut adit another crosscut leads to the east. The first 30 feet of this crosscut is in limestone. The last 140 feet is in black and brown argillite and argillaceous limestone. These two members, the limestone and argillite, have at their contact a fault striking N. 45° E. and dipping 45° SE. A drift 25 feet east of this fault extends S. 30° W. for 450 feet. This drift has been driven on a greenish siliceous band that dips 80° W. and carries disseminated flakes of molybdenite; grains of pyrite, pyrrhotite, and chalcopyrite also occur. Along this siliceous band there are patches of garnet which also carry scattered molybdenite. In places blebs of calcite act as gangue for the molybdenite. The molybdenite is extremely spotty, the best being concentrated between 60 and 100 feet along the drift. In the last 300 feet of the drift it is present in only two places, at the face and about 100 feet in front of the face.

The siliceous band at the northernmost end of the drift has been displaced by the aforementioned 45°-angle fault, but the direction and amount of displacement are not known.

Only one outcrop of the siliceous band was seen on the surface. Here it was in the form of a sheared zone about 2 feet thick, striking N. 25° E. and dipping vertically. No sulfide minerals were seen.

From the above description, it would appear that no commercial production of molybdenite can be expected from this deposit.

GERMANIA AREA[89]

Sec. 13, T. 29 N., R. 37 E.

The Germania mine [which in 1954 was under lease and option by Penticton Tungsten Mines, Ltd., of British Columbia, Canada] is in the south end of the Huckleberry Mountains near the center of the SW¼ sec. 13, (29-37E). The property is most easily reached by road from Springdale on the east or from Reardan on the south via Wellpinit. Other roads lead south from Fruitland and eastward from an abandoned part of State Highway 22 near the old Detillion bridge site on Spokane River.

The low mountainous terrane of the Germania camp is the subdued southern end of the Huckleberry Mountains where they approach Spokane River. The main topographic features consist of northeastward-trending spurs with many lateral ridges flanked by broad ravines. Near the head of one of these ravines the Germania camp is located at an elevation of about 3,500 feet, 500 to 600 feet below the summits of the principal ridges. The ravine drains into Sand Creek, which flows southeastward into the Spokane.

[89] Culver, H. E., and Broughton, W. A., Tungsten resources of Washington: Washington Div. Mines and Geology Bull. 34, pp. 77-79, 1945.

Water at the mine is obtained from springs or shallow wells and also from ground water stored on the third level, lowest of the mine workings. The forested slopes and ridges provide sufficient timber for mining purposes.

The Germania tungsten veins (fig. 4) are enclosed in a medium-grained to porphyritic granitoid stock that is elongated northeastward parallel to the regional strike of the metasedimentary rocks which it intrudes. (†) This mass occupies 8 to 10 square miles exclusive of a narrow connection on the west with a larger batholithic mass of the Loon Lake granite. The metasedimentary rocks that almost encircle the stock consist predominantly of slates and argillites with minor beds of quartzite and dolomite on the west. That only a small amount of the stock has been removed by erosion is indicated not only by its topographic position but by a small roof pendant of argillite adjacent to the vein zone.

No part of the granitic mass is gneissoid; its chief structural feature is a set of longitudinal joints that dip steeply. The metasedimentary rocks strike N. 20° to 30° E. and dip vertically or steeply southeast, the latter being most likely an overturn to the northwest. The vein that has furnished the major portion of the tungsten produced strikes about N. 20° E., essentially parallel to the regional trend of the metasedimentary rocks and to the elongation of the stock itself. Several other veins mainly east of the one that has been mined are essentially parallel to it, suggesting a set of longitudional fractures along which mineralization has occurred.

The principal vein at the Germania ranges in width from a few inches to a little more than 3 feet. At the south end of the main level it narrows to 2 or 3 inches. Some 500 feet above this point, on the summit of the ridge, the width is 4 to 5 inches. The more heavily mineralized parts of the vein have been mined out, and only remnants of the wider portions remain, some of which show aggregates of black wolframite several inches across. Wolframite (var. feberite) is the principal mineral, being much more abundant than pyrite, scheelite, and galenobismutite, on and above the main level. The third level from the top, some 500 feet below the summit of the main ridge where the vein is exposed, shows wolframite decreasing markedly and being superseded by molybdenite. According to Mr. Becker, former superintendent at the Germania, the tungsten veins at this depth are lensing out; and as they do, the molybdenite and wolframite formerly present in the veins are found sparsely distributed through the granite rock, immediately underlying the veins. Molyb-

(†) Bancroft, Howland, The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550, pp. 113-114, 1914. Weaver, Charles E., The mineral resources of Stevens County: Washington Geol. Survey Bull. 20, pp. 59-61, 87-89, 1920.

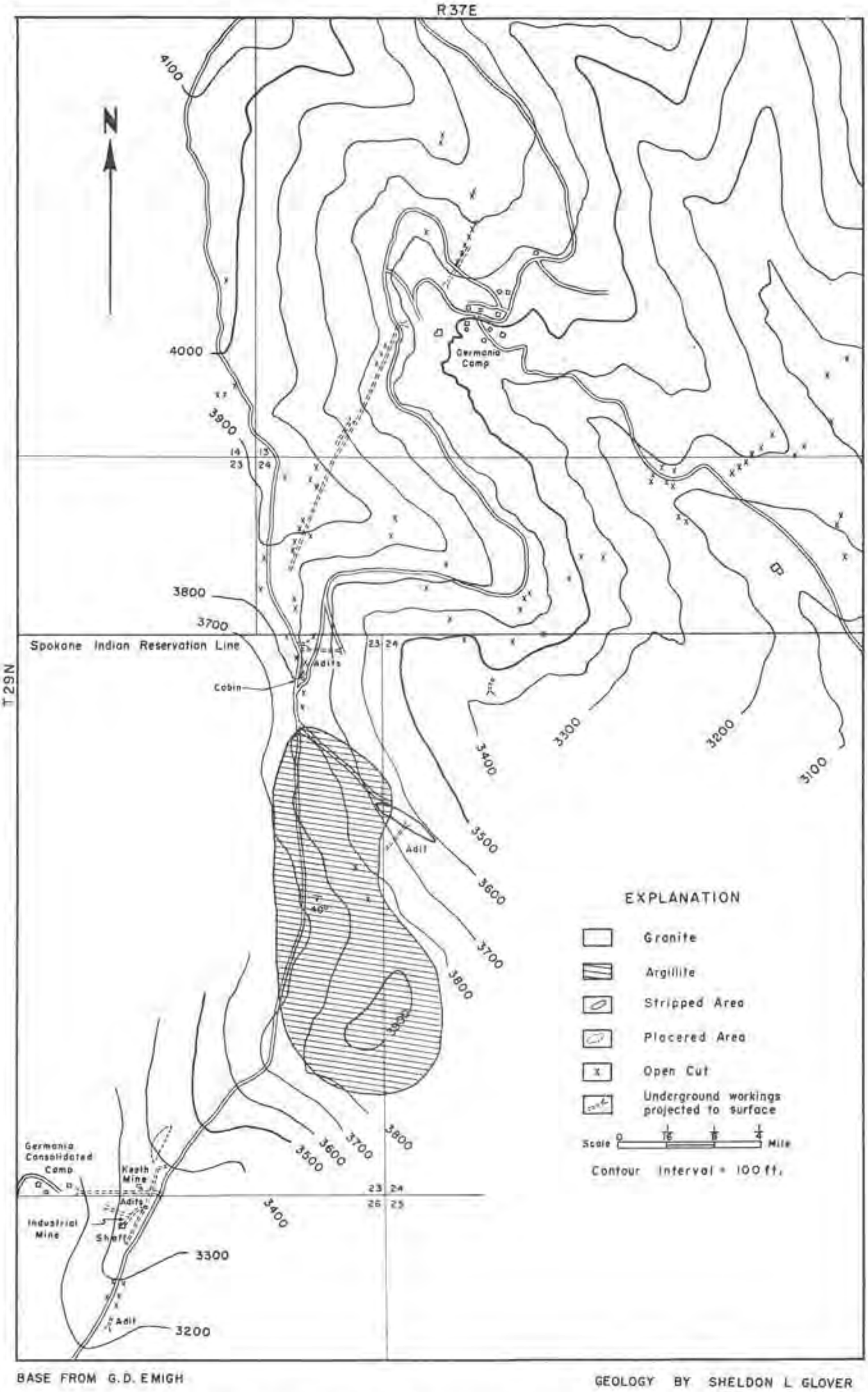


FIGURE 4—Geologic map of the Germania area, showing topography and location of mine workings.

denite is the more prevalent mineral at this depth. The most notable gangue mineral observed in the gray to white quartz is a dark-green chlorite that occurs in clots up to 2 or more inches across, entirely by itself and not associated with other minerals. The vein has generally sharp boundaries with the enclosing granite. The granite on either wall shows a lack of intense hydrothermal alteration. The workings on the summit of the ridge to the southwest show the sharp walls of the vein bordered in places by a fringe of sericite with cleavage surfaces normal thereto.

Other veins that lie mainly to the east of the main Germania lead, although mineralized in places, are narrow for the most part and have been opened by several open cuts and short adits. One of these, the Roselle vein, has produced ore. Recent work underground by the Tungsten Mining and Milling Co., both to the east and west of the main Germania lead, failed to reveal that there had been any mineralization of economic importance. Also, work on the northward continuation of the Germania leads up to 1953 failed to reveal anything of significance.

The Germania Consolidated Mines, Inc. of Spokane controls 400 acres in secs. 23, 24, and 26, (29-37E). The holdings are south and southwest of the Germania property along the strike of the tungsten-bearing veins, and include the old Keeth and Industrial Tungsten properties. The mine is accessible by the same roads that service the Germania.

The main topographic feature is the long ridge trending southwest from the Germania property. Tungsten-bearing veins are exposed on the east side of the north end of this ridge as well as on the top and west slope of the south end. Timber is abundant, and water can be obtained throughout the year.

Except for a small roof pendant of quartzite and slate that covers about half a mile of the ridge top, the bedrock is a part of the same granite stock that underlies the Germania ground. Both the granite and the roof pendant are cut by a series of parallel quartz veins that strike about N. 20° E. and dip from 70° to 80° SE. There appear to be at least three distinct veins, and it is possible that there are actually several more. Future development work accompanied by careful mapping will be necessary to establish their relationships.

The veins range from a fraction of an inch to about a foot in thickness and probably average 4 or 5 inches. They are composed of bluish-gray glassy quartz that in places shows development of individual quartz crystals several inches long. The quartz contains considerable pyrite and occasional crystals of wolframite (var. feberite), scheelite, and molybdenite. Parts of the veins contain sufficient wolframite to constitute ore. In the wider portions of the veins the wolframite occurs as aggregates of large crystals several inches across, while in the narrower portions the wolframite generally occurs as minute individual crystals. Although scheelite occurs in amounts subordinate to wolframite it is in places abundant enough to appreciably raise the tungsten content of the veins. Scheelite crystals ranging from minute specks to half an inch across were observed. Wolframite crystals are often bordered and cut by minute scheelite seams, and some scheelite crystals have the tabular shape of wolframite which suggests an alteration of wolframite to scheelite. Molybdenite crystals less than a quarter of an inch across are common throughout the veins, and in some parts of the veins molybdenite crystals up to half an inch across are very abundant along the footwalls. The only gangue mineral observed, besides quartz, is a dark-green chlorite which usually forms isolated crystal bunches in the veins.

The major part of the development work has been done just west of the ridge crest at the south end of the property. It consists, at the old Industrial Tungsten property, of a 220-foot shaft with 150 feet of drifts; and at the old Keeth property, a 650-foot adit with about 2,000 feet of drifts and raises along which considerable stoping has been done, several short adits, and numerous open cuts and trenches. On the east slope of the ridge at the north end of the property three short adits with a small amount of drifting have been driven westward into the ridge and considerable trenching has been done. The locations of the several workings are shown on figure 4. The best molybdenite showing is probably at the old Industrial Tungsten property where a drift has been driven 30 feet north of the shaft on the 200-foot level. Here in the face the vein splits and a horse of granite occurs. The east vein is 4 inches thick and the west, 4 to 8 inches thick. Considerable molybdenite is present both in the veins and in the wall rock, but no wolframite is visible. It is barely possible some molybdenite could be produced from this area. At the old Keeth property another area that may show molybdenite potentiality is at the northeast end of the main adit level on No. 3 vein 65 feet above sill level. Here the quartz vein has been exposed over a distance of about 100 feet. It has irregular walls showing gradational contacts with the granite, and averages between 6 inches and a foot in thickness. The vein contains in places considerable molybdenite. Pyrite, wolframite, scheelite, and minor amounts of chalcopyrite are also present. For about 2 feet on either side of the vein the wall rock has been chloritized and impregnated by the sulfides. It is reported that bunches of wolframite are occasionally found in this altered zone.

This occurrence of a vein having irregular walls, wall rock alteration, and a quantity of sulfides is quite in contrast to the other veins in the area, which have quite regular sharp walls and exhibit little if any alteration of the adjacent granite.

In 1953, according to the operators, small shipments of wolframite concentrate were being made. During the milling, which consisted of jigging and tabling, molybdenite and pyrite became released to contaminate the tungsten. Because these two contaminants must be thrown out in order to obtain a satisfactory wolframite concentrate, the operators indicated that they were seriously considering flotation cells for the purpose of saving the molybdenite and sending the pyrite to the tailings. Thus, there may be an opportunity here for a small production of byproduct molybdenite.

WESTERN MOLYBDENUM COMPANY MINE, CHEWELAH DISTRICT, STEVENS COUNTY, WASHINGTON[25]

By

John R. Cooper[26]

[25] Publication by the Washington State Division of Mines and Geology authorized by the Director, U. S. Geological Survey.

[26] Geologist, U. S. Geological Survey.

CONTENTS

ILLUSTRATIONS

WESTERN MOLYBDENUM COMPANY MINE, CHEWELAH DISTRICT, STEVENS COUNTY, WASHINGTON

By John R. Cooper

ABSTRACT

The Western Molybdenum Co. mine was opened many years ago to obtain copper. The only production was several carloads of crude copper ore shipped during World War I. An unsuccessful attempt to produce molybdenum was made in 1939-1941.

The deposit consists of steeply dipping, northeast-striking veins in monzonite and marble, carrying molybdenite, pyrite, chalcopyrite, scheelite, and some quartz. Northwest-striking faults cut and offset the veins as much as 10 feet. The main vein, which contains all the known ore, is developed by four levels to a depth of 293 feet. It contains ore shoots from a few inches to 4 feet wide and up to 130 feet long, carrying about 1 percent MoS_2, 1 percent Cu, and 0.15 percent WO_3.

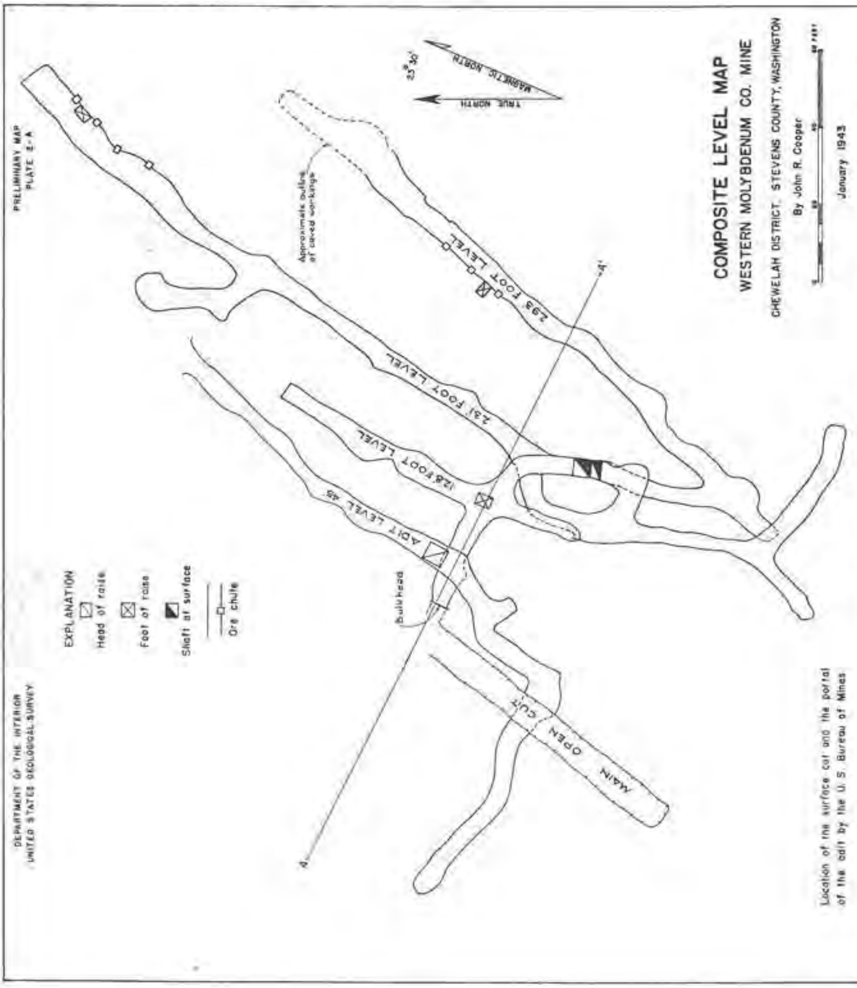
INTRODUCTION

A preliminary report on the Western Molybdenum Co. property, based on a brief examination of the surface geology, was made by C. A. Anderson of the U. S. Geological Survey in October 1942. At that time the mine was filled with water. In December 1942 the underground workings were unwatered through a preliminary development loan granted by the Reconstruction Finance Corporation. J. J. Collins and J. R. Cooper of the U. S. Geological Survey visited the property December 28-29, 1942. J. R. Cooper mapped the underground and surface geology between December 30, 1942 and January 6, 1943. During this period, engineers of the U. S. Bureau of Mines sampled the mine workings and determined the relative locations and surface elevations of the three shafts, the tunnel portal, and the three open cuts. The underground mapping was done with compass and tape. The surface geology was mapped by running pace-compass traverses between points located by the Bureau of Mines. About 6 inches of snow covered the ground when the work was done.

The only previous descriptions of the mine known to the writer are by C. A. Anderson (1942, manuscript report in the files of U. S. Geological Survey) and by C. E. Weaver (1920, pp. 153-154).

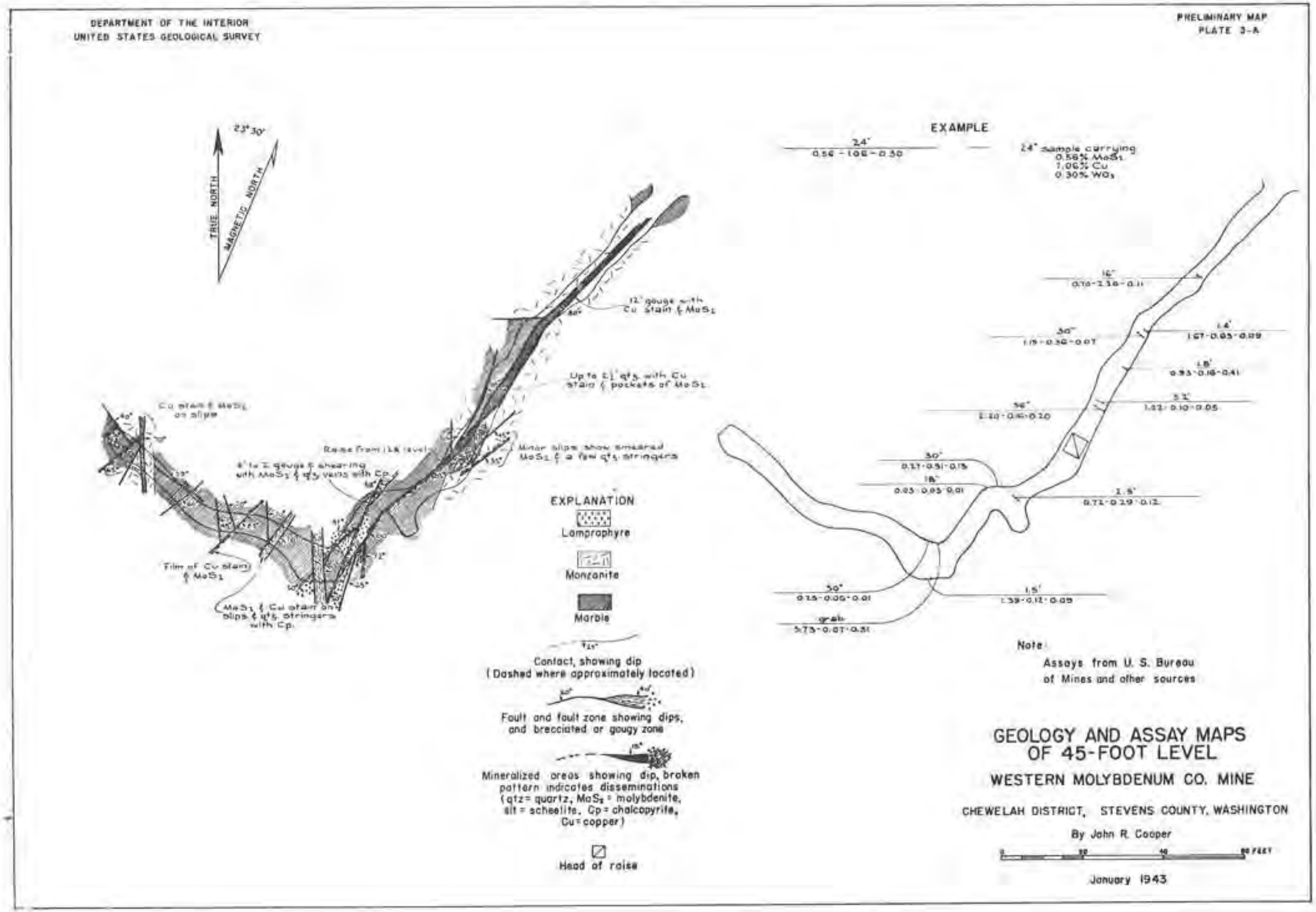
LOCATION

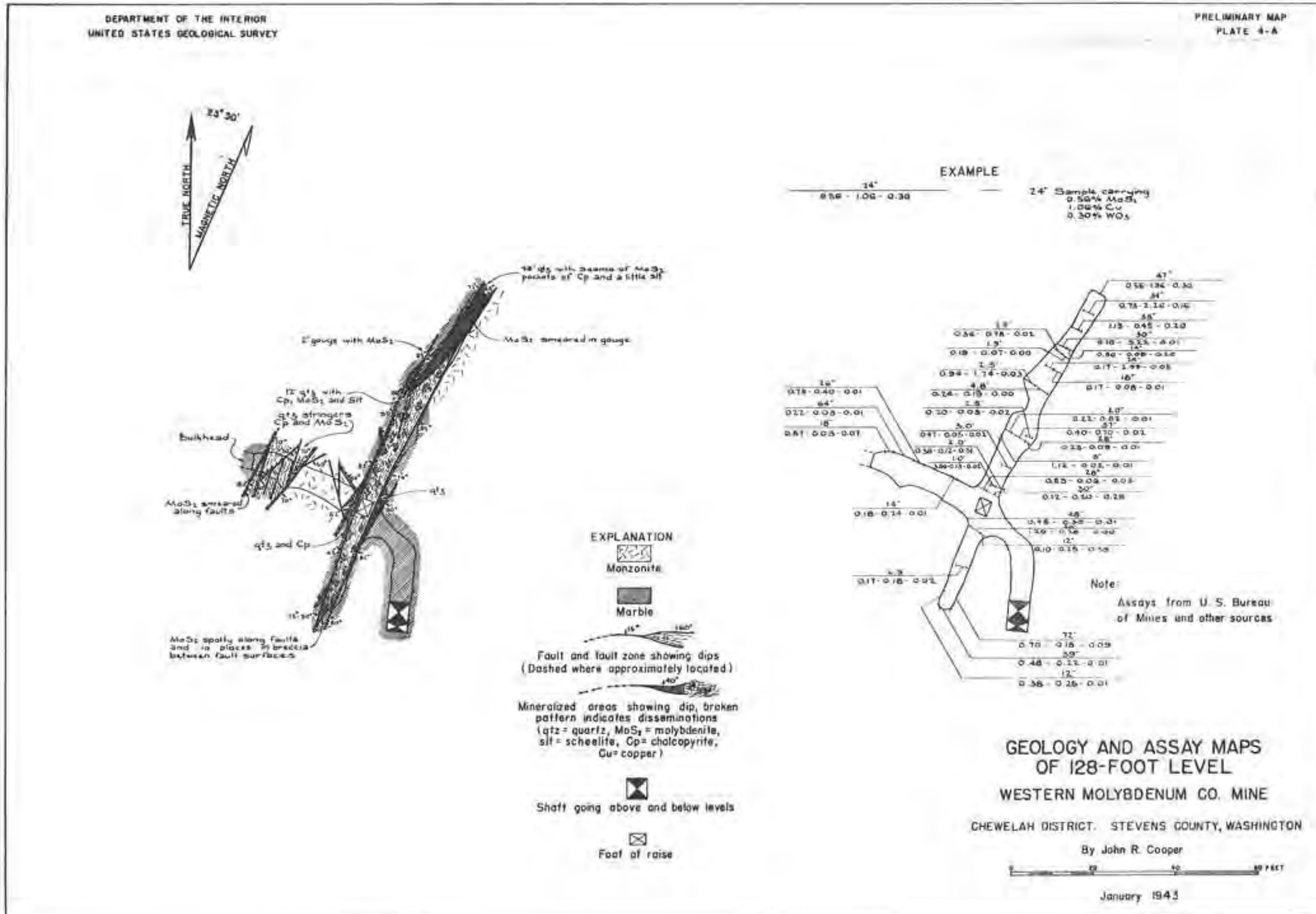
The Western Molybdenum Co. property is in sec. 7, T. 32 N., R. 41 E., 2 miles northeast of Chewelah, Washington. A good dirt road runs down from the property to Chewelah, which is served by the Great Northern Railway. There is plenty of timber for mining purposes. A moderate supply of water may be obtained from the mine itself and from nearby wells.



DEVELOPMENT

The mine is developed by the Main shaft 300 feet deep and by about 885 feet of level workings (pls. 1-A, 2-A, and 7-A). Three levels connect with the shaft at depths of 128, 231, and 293 feet. The 128-foot level has about 150 feet of workings (pl. 4-A), the 231-foot level has 353 feet of workings (pl. 5-A), and the 293-foot level, 206 feet of workings (pl. 6-A). There is also an adit level, which is 45 feet lower than the collar of the shaft and consists of a drift 110 feet long and a crosscut 60 feet to the northwest (pl. 3-A).


DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
PRELIMINARY MAP
PLATE 3-A
23° 30'
TRUE NORTH
MAGNETIC NORTH
12' gouge with Cu stain & MoS_2
80°
Up to 2½' qtz. with Cu stain & pockets of MoS_2
Cu stain & MoS_2 on slips
40°
Raise from 128 level
6' to 2' gouge & shearing with MoS_2 & qtz. veins with Cp.
Minor slips show smeared MoS_2 & a few qtz. stringers
45°
35°
72°
25°
Film of Cu stain & MoS_2
MoS_2 & Cu stain on slips & qtz. stringers with Cp.
EXPLANATION
Lamprophyre
Monzonite
Marble
Contact, showing dip
(Dashed where approximately located)
Fault and fault zone showing dips, and brecciated or gougy zone
Mineralized areas showing dip, broken pattern indicates disseminations
(qtz = quartz, MoS_2 = molybdenite, slt = scheelite, Cp = chalcopyrite, Cu = copper)
Head of raise
EXAMPLE
24"
0.56 - 1.06 - 0.30
24" sample carrying
0.56% MoS_2
1.06% Cu
0.30% WO_3
16"
0.70 - 2.36 - 0.11
30"
1.15 - 0.30 - 0.07
1.4'
1.67 - 0.85 - 0.09
1.8'
0.93 - 0.16 - 0.41
3.2'
1.02 - 0.10 - 0.05
36"
2.20 - 0.16 - 0.20
30"
0.27 - 0.31 - 0.15
18"
0.03 - 0.05 - 0.01
2.5'
0.72 - 0.29 - 0.12
30"
0.25 - 0.06 - 0.01
1.5'
1.39 - 0.12 - 0.09
grab
5.73 - 0.07 - 0.31
Note:
Assays from U. S. Bureau of Mines and other sources
GEOLOGY AND ASSAY MAPS OF 45-FOOT LEVEL
WESTERN MOLYBDENUM CO. MINE
CHEWELAH DISTRICT, STEVENS COUNTY, WASHINGTON
By John R. Cooper
0 20 40 60 FEET
January 1943


DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
PRELIMINARY MAP
PLATE 4-A
TRUE NORTH
MAGNETIC NORTH
23°30'
Bulkhead
Monzonite
Marble
EXPLANATION
Fault and fault zone showing dips
(Dashed where approximately located)
Mineralized areas showing dip, broken pattern indicates disseminations
(qtz = quartz, MoS_2 = molybdenite, slt = scheelite, Cp = chalcopyrite, Cu = copper)
Shaft going above and below levels
Foot of raise
EXAMPLE
24" Sample carrying 0.58% MoS_2 1.06% Cu 0.30% WO_3
Note:
Assays from U. S. Bureau of Mines and other sources
GEOLOGY AND ASSAY MAPS
OF 128-FOOT LEVEL
WESTERN MOLYBDENUM CO. MINE
CHEWELAH DISTRICT, STEVENS COUNTY, WASHINGTON
By John R. Cooper
January 1943

An inclined raise from the 128-foot level connects with this adit. Several small stopes and two short raises have been opened from the 293-foot level, one of the latter connecting with the shaft at 265 feet. The shaft is timbered for the entire depth, the rock being visible only in places. The tunnels are untimbered except near overhead stopes and for short sections in the fault zone on the 231- and 293-foot levels.

Numerous surface cuts are on the property as well as two inaccessible shafts that are northeast of the Main shaft. The No. 2 shaft is said to be 80 feet deep. The Standard shaft is of unknown depth, but the size of the dump indicates about 500 feet of workings (pl. 1-A).

HISTORY AND PRODUCTION

The mine, originally called the Juno-Echo mine, was located and developed for copper. The only production on record with the U. S. Bureau of Mines is 47 tons of crude ore shipped by the Juno-Echo Mining and Milling Co. in 1916, which averaged 2.4 percent copper, 0.004 oz. gold, and 0.19 oz. silver per ton. According to Weaver (1920) the production consisted of three carloads that were shipped in 1917.

In February 1939 the Western Molybdenum Co. obtained a lease on the property. A flotation mill was installed, and an attempt was made to produce a molybdenum concentrate. According to report, 300 or 400 tons of ore was mined and milled. The separation of molybdenite from the associated chalcopyrite was not complete, and the concentrates did not reach the necessary grade. No concentrates were sold, and the company failed. The last operations were in September 1941. The mine filled with water and remained flooded until December 1942, when it was pumped out.

GENERAL GEOLOGY

The Western Molybdenum Co. mine is near the contact between a dark-gray monzonite stock and a limestone phase of the Chewelah argillite (Paleozoic?) of Weaver. Several narrow lamprophyre dikes were found in the latter formation.

The Chewelah argillite forms a band 3 miles wide, extending 9 miles northeastward from Chewelah to where it is cut off by the batholith of Weaver's Loon Lake granite. According to Weaver (1920) the Chewelah argillite is in the center of a syncline that is closed and slightly overturned toward the west. In general, the formation consists of 4,000 feet of interbedded quartz mica schist, phyllite, argillite, calcareous argillite, dolomitic limestone, argillaceous limestone, and narrow bands of quartzite. On the Western Molybdenum Co. property, the exposed, metasedimentary rocks are almost wholly fine- to medium-grained marble, in part white, but more commonly pale green because of the presence of tremolite and serpentine. At a few places the rock has been completely replaced by contact metamorphic silicates, of which tremolite is the most abundant. Arkosic quartzite is exposed near the Main shaft. The quartzite presumably represents a sandstone bed, but its attitude and relationship to the limestone could not be determined.

The monzonite is part of a stock extending into the eastern part of the property. It is dark-gray hornblendic rock resembling diorite. It is here classified as monzonite on the basis of a single thin section that contains about 35 percent microcline and apparently once contained about the same amount of plagioclase. Quartz is a very minor constituent. Sericite, zoisite, calcite, and other hydrothermal minerals are abundant. The monzonite may be related to Weaver's Loon Lake granite, but the nearest mapped contact of the latter is 4 miles east and 10 miles north of the Western Molybdenum Co. mine.

The lamprophyre dikes are porphyritic with dominant hornblende phenocrysts and lesser phenocrysts of augite and biotite, and are therefore camptonites. They are older than the metallic mineralization (pl. 3-A).

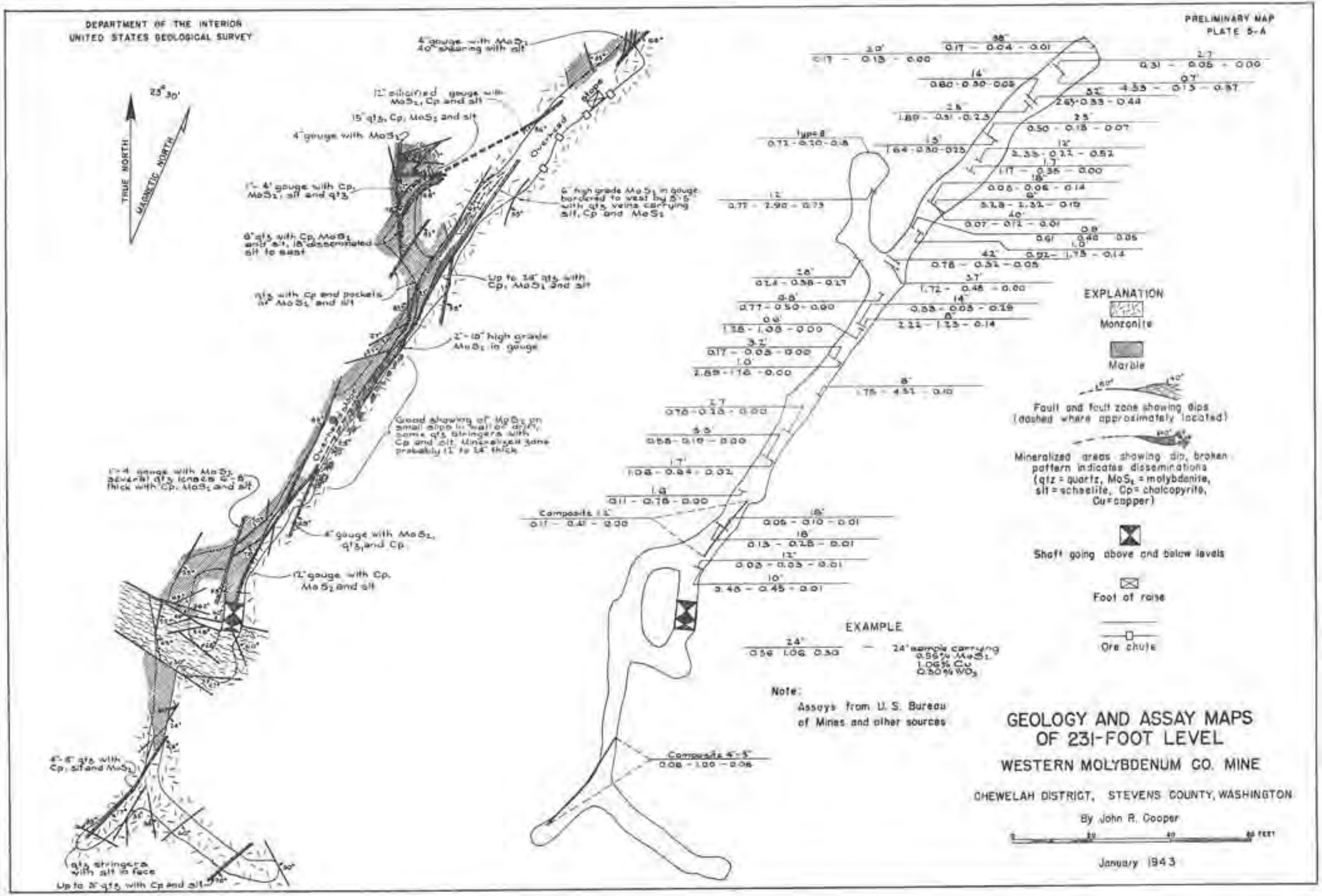
STRUCTURE

The exposed contacts between marble and monzonite have steep dips. The attitude of bedding could not be determined positively. At four or five places in the mine workings the marble is banded, the bands striking close to N. 15° W. and dipping 55° to 85° E. This structure may be the original bedding or may be due to the later intrusion of the monzonite. It is roughly parallel to the nearby monzonite contact and departs considerably from the regional structure of the Chewelah argillite, which Weaver gives as N. 23° E., 70° NW. in this vicinity.

Fault fissures, which strike northeast and dip more steeply than 65°, have been mineralized with quartz and metallic minerals. Six of these fissures, arranged en échelon, are found in the north-trending zone between the Main shaft and the Standard shaft, as shown on the geologic map (pl. 1-A). It is reasonable to suppose that similar mineralized fissures occur north and south of the mapped area. Only one of the fissures is known to have yielded ore in commercial quantities. This is the "main vein," developed by the Main open cut, the adit, and the Main shaft.

The main vein strikes northeast and dips about 75° SE. Frictional drag effects and slickensides show that in the most recent movement the hanging-wall block moved down and to the northeast with reference to the footwall block. This movement was post-mineral, as the ore minerals are smeared out and burnished along the slip surfaces.

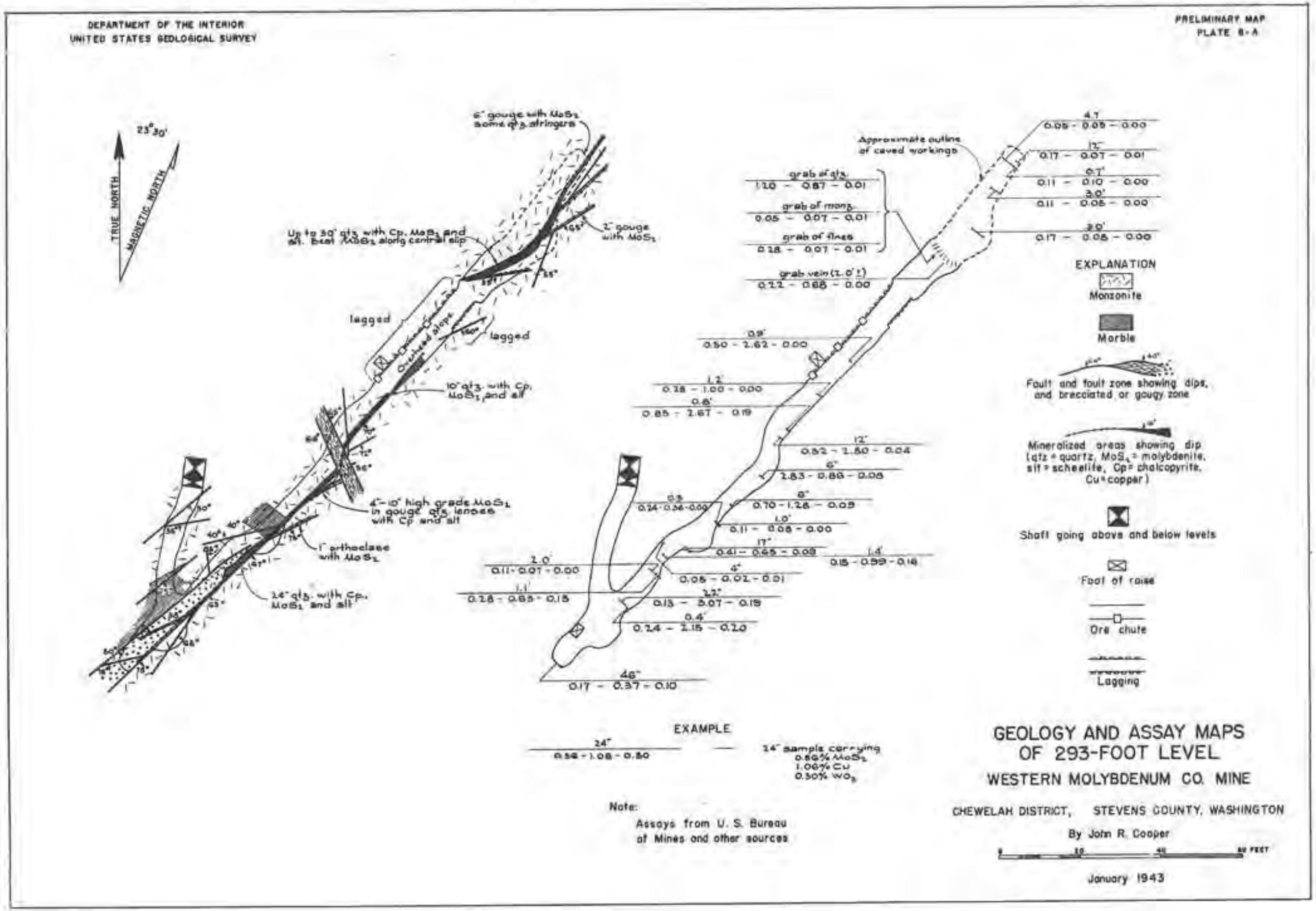
Post-mineral movements are also expressed by faults striking northwest and dipping 30° to 80° NE. These cut and offset the mineralized fractures but are themselves barren. The amount of vein

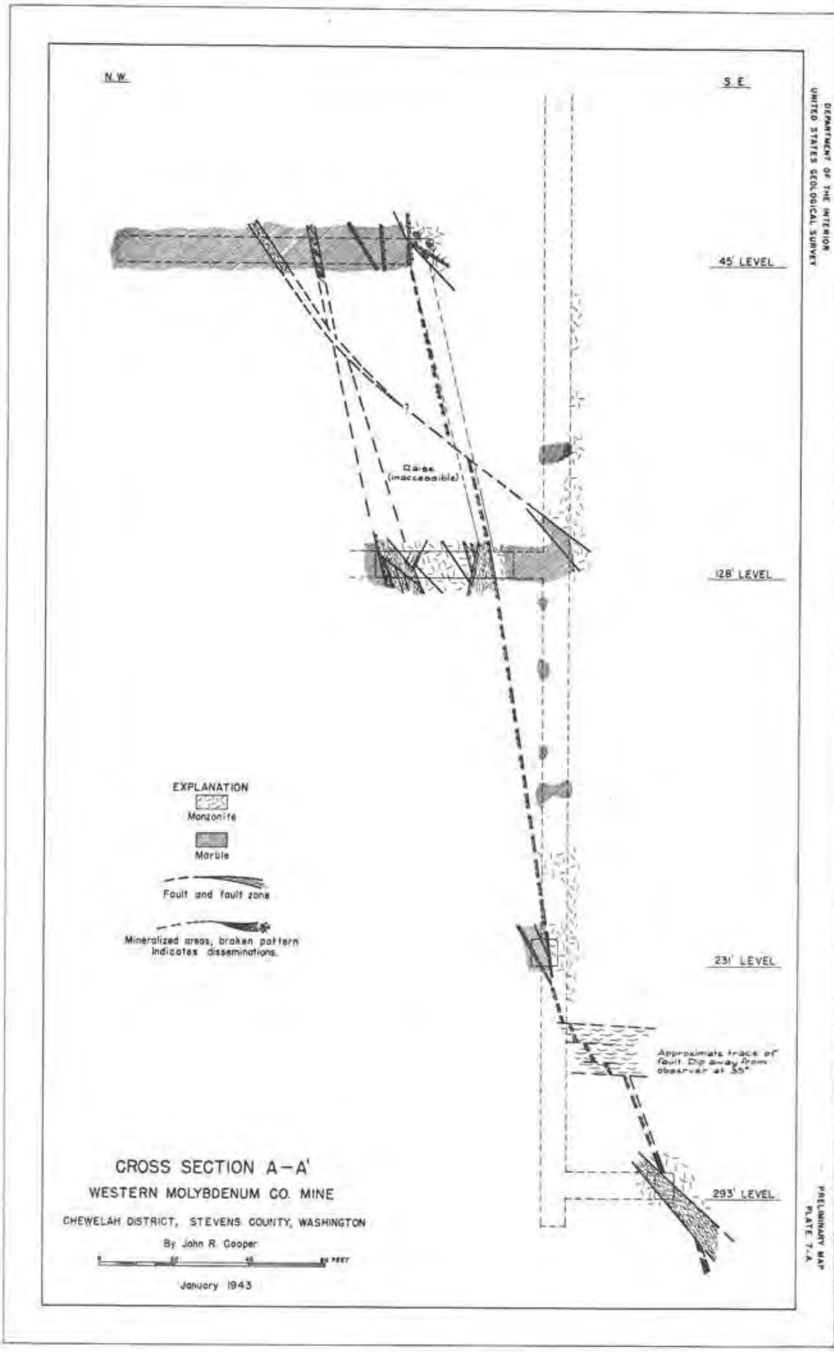

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
PRELIMINARY MAP
PLATE 5-A
TRUE NORTH
MAGNETIC NORTH
Overhead
Stope
4" gouge with MoS2
1'-4' gouge with Cp, MoS2, slt and qtz
Up to 24" qtz with Cp, MoS2 and slt
qtz with Cp and pockets of MoS2 and slt
2"-10" high grade MoS2 in gouge
4" gouge with MoS2, qtz and Cp
12" gouge with Cp, MoS2 and slt
qtz stringers with slt in face
Up to 3' qtz with Cp and slt
EXPLANATION
Monzonite
Marble
Fault and fault zone showing dips (dashed where approximately located)
Mineralized areas showing dip, broken pattern indicates disseminations (qtz = quartz, MoS2 = molybdenite, slt = scheelite, Cp = chalcopyrite, Cu = copper)
Shaft going above and below levels
Foot of raise
Ore chute
EXAMPLE
24"
0.56 1.06 0.30
24" sample carrying 0.56% MoS2 1.06% Cu 0.30% WO3
Note:
Assays from U. S. Bureau of Mines and other sources
GEOLOGY AND ASSAY MAPS OF 231-FOOT LEVEL
WESTERN MOLYBDENUM CO. MINE
CHEWELAH DISTRICT, STEVENS COUNTY, WASHINGTON
By John R. Cooper
January 1943

displacement in a horizontal direction (only direction determinable) ranges from a few inches to an observed maximum of a few feet. The largest of these faults cuts off the main vein near the shaft on the 231-foot level (pl. 5-A). The vein ends against an 8-foot zone of shearing and gouge which strikes N. 60° W. and dips 35° NE. On the southwest or footwall side of the fault, the vein is offset about 10 feet to the southeast (in part by drag on the fault). The actual displacement on the fault may have been considerable, for the southwest segment of the vein is characterized by relatively weak shearing and only 4 to 8 inches of quartz, which soon disappears. It is, of course, possible that the main vein was not discovered southwest of the fault, but this is considered improbable because of the relationships exposed on the 293-foot level and described in the following paragraph.

The fault splits up into a wide zone of shearing and smaller faults below the 231-foot level. One branch is exposed on the 293-foot level 95 feet from the northeast face and offsets the vein 4 feet horizontally (pl. 6-A). The main zone of movement crosses a little farther north where the drift is lagged, and therefore could not be shown on the map. However, in the small stope above this portion of the drift, it is seen to consist of several small faults offsetting the vein an aggregate of about 4 feet horizontally. In every case here, as in the branch fault visible in the drift, the vein is offset in the same direction, the southwestern segment having been displaced southeastward with respect to the northeastern segment. Thus the aggregate offsetting of the vein on the 293-foot level is essentially the same, both in direction and in amount, as that on the 231-foot level, as pointed out in the preceding paragraph.

Another fault, characterized by several feet of gouge and shearing, crosses the east end of the crosscut on the 45-foot or adit level (pl. 3-A). This fault strikes N. 4° W. and dips 60° E. It cuts off a lamprophyre dike and possibly one stringer of the main vein. The fault has been projected downward on cross section A-A′ (pl. 7-A) and tentatively correlated with a fault which is exposed back of the timbers 114 feet down the shaft. If the correlation is correct, the fault flattens with depth.


DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
PRELIMINARY MAP
PLATE 8-A
TRUE NORTH
MAGNETIC NORTH
23°30'
6" gouge with MoS_2 some qtz stringers
Up to 30" qtz with Cp, MoS_2 and slt. Best MoS_2 along central slip
2" gouge with MoS_2
lagged
Overhead stope
10" qtz with Cp, MoS_2 and slt
4"–10" high grade MoS_2 in gouge, qtz lenses with Cp and slt
1" orthoclase with MoS_2
24" qtz with Cp, MoS_2 and slt
Approximate outline of caved workings
grab of qtz
1.20 - 0.87 - 0.01
grab of monz
0.05 - 0.07 - 0.01
grab of fines
0.28 - 0.07 - 0.01
grab vein (2.0'±)
0.22 - 0.68 - 0.00
4.7'
0.05 - 0.05 - 0.00
12"
0.17 - 0.07 - 0.01
0.7'
0.11 - 0.10 - 0.00
3.0'
0.11 - 0.05 - 0.00
3.0'
0.17 - 0.08 - 0.00
0.9'
0.50 - 2.62 - 0.00
1.2'
0.38 - 1.00 - 0.00
0.8'
0.85 - 2.67 - 0.19
12"
0.32 - 2.80 - 0.04
6"
2.83 - 0.88 - 0.08
0.3'
0.24 - 0.36 - 0.00
8"
0.70 - 1.28 - 0.09
1.0'
0.11 - 0.08 - 0.00
17"
0.41 - 0.65 - 0.08
1.4'
0.15 - 0.99 - 0.16
2.0'
0.11 - 0.07 - 0.00
4"
0.05 - 0.02 - 0.01
1.1'
0.28 - 0.65 - 0.13
27"
0.13 - 3.07 - 0.19
0.4'
0.24 - 2.15 - 0.20
46"
0.17 - 0.37 - 0.10
EXPLANATION
Monzonite
Marble
Fault and fault zone showing dips, and brecciated or gougy zone
Mineralized areas showing dip (qtz = quartz, MoS_2 = molybdenite, slt = scheelite, Cp = chalcopyrite, Cu = copper)
Shaft going above and below levels
Foot of raise
Ore chute
Lagging
EXAMPLE
24"
0.56 - 1.08 - 0.30
24" sample carrying 0.56% MoS_2 1.08% Cu 0.30% WO_3
Note: Assays from U. S. Bureau of Mines and other sources
GEOLOGY AND ASSAY MAPS OF 293-FOOT LEVEL
WESTERN MOLYBDENUM CO. MINE
CHEWELAH DISTRICT, STEVENS COUNTY, WASHINGTON
By John R. Cooper
January 1943


N.W.
S.E.
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
45' LEVEL
Raise (inaccessible)
128' LEVEL
EXPLANATION
Monzonite
Marble
Fault and fault zone
Mineralized areas, broken pattern indicates disseminations.
231' LEVEL
Approximate trace of fault. Dip away from observer at 55°
293' LEVEL
PRELIMINARY MAP
PLATE 7-A
CROSS SECTION A—A'
WESTERN MOLYBDENUM CO. MINE
CHEWELAH DISTRICT, STEVENS COUNTY, WASHINGTON
By John R. Cooper
FEET
January 1943

ORE DEPOSITS

The main vein, which is developed by the surface cut and the four levels, is characterized in places by a single gouge band a few inches thick and elsewhere by a zone of brecciation and shearing 4 to 6 feet wide. Here and there, subordinate faults branch off from it at small angles.

The primary ore is a mixture of quartz, molybdenite, pyrite, chalcopyrite, and scheelite, with varying amounts of the sheared wall rock. Most of the molybdenite is smeared out in the gouge and occurs as films along the shear planes. The richest molybdenum ore is in gouge bands with at most only narrow stringers of quartz. Chalcopyrite and scheelite, on the other hand, are most abundant in the quartz ore. It follows, therefore, that there are two kinds of ore—gouge ore relatively rich in molybdenum, and quartz ore relatively rich in copper and tungsten. The two are generally associated and would have to be mined together. On the geologic maps accompanying this report, definite bands of gouge ore and quartz are shown by cross hatches; disseminations of ore minerals are shown by broken cross hatches. The assay maps give the results of sampling by the U. S. Bureau of Mines.

The ore in the surface cut has been oxidized to molybdite, limonite, malachite, and azurite. There are lesser amounts of these secondary minerals in the adit level, but apparently none in the lower levels of the mine.

The ore bodies are lenticular in plan and range from a few feet to 130 feet in length and from a few inches to 4 feet in width. The average grade is close to 1 percent MoS_2, 1 percent Cu, and 0.15 percent WO_3. The precious-metal content is very low; composite samples carrying a trace to 0.02 oz. of gold and a maximum of 0.20 oz. of silver per ton. As far as is known, the only ore outside of the main vein is in the short dog-leg crosscut on the 231-foot level.

The ore was formed by medium- or high-temperature hydrothermal solutions. Deposition was localized along the northeast-trending faults in marble, monzonite, or lamprophyre. Apparently the best ore was deposited along the most open passageways regardless of host rock. The thickest ore is along the more northerly trending segments of the vein and at sharp bends or splits (pls. 3-A, 4-A, 5-A, and 6-A). The post-mineral movement on northeast-trending faults would cause openings along more northerly segments. Pre-mineral movements may have had the same effect. The main shoot is at or near the contact of marble and monzonite in the upper levels, and nearly all the better ore showings are near marble-monzonite contacts on at least one side of the vein.

REFERENCES

Anderson, C. A., 1942, Report on a brief examination of the property of Western Molybdenum Company, Chewelah, Stevens County, Washington (unpublished report in files of U. S. Geological Survey).

Weaver, C. E., 1920, The mineral resources of Stevens County: Washington Geol. Survey Bull. 20, 350 pp.*

*End of U. S. Geological Survey report by John R. Cooper.

WHATCOM COUNTY

Silver Creek Prospect

NE¼ and SE¼ sec. 8, T. 40 N., R. 13 E.

The Silver Creek prospect is located 2 miles south of the international boundary between Canada and the United States and 1½ miles west of the Skagit River. It is at an altitude of about 2,200 feet, which at the prospect is about 300 feet above the creek bottom. Silver Creek flows from west to east to the Skagit River and has carved a steep-walled valley in volcanic and granitic rock.

The property can be reached most easily by going first to Hope, B. C. About 1½ miles west of Hope a private logging road 42 miles long leads up the Silver River, over into the Skagit drainage, and across the international boundary to logging operations in the vicinity of the mouth of Silver Creek. This road in 1950 was owned by the Decco-Walton Lumber Co. of Everett, and their permission had to be obtained before it could be used. From the mouth of Silver Creek a trail leads for 1½ miles up the north bank of Silver Creek to a cabin.

The property consists of four claims held by location. The owners are Roy Davis, George Hunt, and A. E. Blockberger of Shelton, Washington (1954). The claims are two abreast and trend approximately north and south, including a deposit on the north side of Silver Creek and one on the south side.

The deposit on the south side of Silver Creek was examined in July 1942 by W. A. G. Bennett and H. E. Culver, then of the staff of the Division of Geology. According to Bennett, it is located in the bed of the easternmost northward-flowing tributary of Silver Creek, just below a small waterfall about 150 feet above the level of the creek. The deposit consists of ¼- to 1-inch stringers of quartz containing scattered chalcopyrite and clusters of molybdenite. The stringers, striking a few degrees west of north, are in granodiorite close to its contact with volcanic rock. At the outcrop the distance across the strike of the quartz stringers is about 10 feet. How far they may be traced along their strike is a question that could not be answered at the time of the examination because of the overburden and brush. On the southeast bank the quartz stringers run into the volcanic rocks which have been intruded by the granodiorite.

As the outcrop area comprises only about 100 square feet, a fair appraisal of the deposit is difficult. However, judging from the examination of similar occurrences, it would seem that no commercial operation can be expected at this location.

On the north side of Silver Creek the deposit is on the west bank of the easternmost southwestward-flowing tributary to Silver Creek, about 300 feet above the level of the creek. The deposit has been developed by an 85-foot adit and several open cuts above it.

The adit has been driven along a fault striking N. 16° E. and dipping 80° W. On the east side of the fault, at the portal a dacitic volcanic breccia is exposed, and on the west side about waist high a granodiorite dike between 3 and 4 feet thick has been intruded into the volcanic breccia. The dike strikes about north and dips 15° W. About 15 feet inside the portal the lower granodiorite-volcanic contact has a quartz stringer ½ inch thick which angles off into the volcanic rock. The area that has been mineralized is exposed in the last 12 feet of the adit. This area is bounded on the south by a subordinate fracture to the main fault extending out to the northwest and dipping 80° S. The mineralization caused a bleaching and silification of the volcanic breccia as chalcopyrite and molybdenite were sparsely distributed through the rock. Apparently the mineralization was controlled by the presence of a fracture zone, as evidenced by strong brecciation. A chip sample of the mineralized area as exposed in the adit gave the following analysis: gold, nil; silver, 0.40 oz. per ton; copper, 1.50 percent; molybdenite, 0.15 percent. The analysis was made by W. H. Ott of Seattle, Washington.

About 64 feet directly above the face of the adit is an open cut. At the east end of the cut is the fault along which the adit is driven. To the east of the fault is fresh volcanic breccia, whereas to the west of the fault and extending for 50 feet is bleached and silicified volcanic breccia, which contains scattered molybdenite and chalcopyrite in fair quantity. This material would undoubtedly assay about 1 percent molybdenite and 2 to 3 percent copper, thus making an interesting ore. However, several open cuts on up the hill only 100 feet beyond this mineralized zone, though they reveal the bleached and silicified volcanic rock, fail to reveal any sulfides. Also, no sign of sulfides can be seen in the small tributary streams flowing just below the adit. Consequently, the mineralized zone would appear to be strongly localized, perhaps roughly circular in horizontal plan, and possibly not more than 50 feet in diameter. If the quantity of sulfides exposed at the surface were exposed in the adit, the property might be considered a good prospect, but because of the geological relationships and the inaccessibility of the property, it would appear to be a poor risk.

APPENDIX

As indicated in the introduction to this report, it was neither feasible nor necessary to examine all the molybdenum occurrences that have been recorded for the state. However, it is recognized that a complete list of such occurrences might prove useful to some investigators. Accordingly, on the following pages all known occurrences are listed, arranged alphabetically by counties. This listing was compiled by Marshall T. Huntting of the staff of the Division of Mines and Geology for the molybdenum section of Bulletin No. 37, Inventory of Washington Minerals, Part 2, Metallic Minerals, a report that is in preparation in 1954 but the publication date of which is yet undetermined. The list is as complete and accurate as possible, but it is based on information that varies widely in reliability, all the way from explicit field notes of staff members of the Division to hearsay and rumors. However, no data known to be erroneous are included.

The occurrences named have been handled in three different ways: Those in the first category are the ones which have been described in the main body of the present report. Those are mentioned by name only, followed by a page number for reference to the foregoing text, where information on them is set forth. The second group are those properties from which a small amount of molybdenite might be produced as a byproduct, or specimen material collected. These are shown in this appendix with descriptions as they will appear in the Metallic Minerals report referred to above. The third category includes those properties containing molybdenite in minute or quite probably noncommercial amounts and also those from which molybdenite has been only reported. These properties have been mentioned by name only. Details of their occurrence will appear in the Metallic Minerals report, when published.

After most of the property names in all three categories is a number in parentheses. This is the number assigned to that property on the index map (fig. 1). The number sequence starts anew for each county. Those properties whose names are not followed by a number are the ones whose location has been but vaguely reported.

In the bibliography, alphabetically arranged by authors, each reference has been assigned a number. These numbers are not consecutive because this bibliography was adapted from Bulletin 37, Part 2, and includes only those references pertaining to molybdenum out of a long list applicable also to other metals. The numbers in bold-face type at the end of each property description indicate the references pertaining to that particular property.

ABBREVIATIONS

The following list of abbreviations is arranged alphabetically and contains all those used in the subsequent listing of molybdenum deposits.

Ag—silver
approx.—approximately
As—arsenic
Au—gold
av.—average, averaging
Ave.—avenue
Be—beryllium
Bi—bismuth
Bros.—Brothers
Bur.—Bureau
C.—Centigrade
Co.—Company
conc.—concentrate, concentrates
cor.—corner
Corp.—Corporation
Cr.—Creek
Cu—copper
cu.—cubic
Dept.—Department
Dev—development
dia.—diameter
dist.—district
Div.—Division
E.—east
Elev—elevation
est.—estimated
et al.—et alibi (and others)
F.—Fahrenheit
Fe—iron
Fk.—Fork
fr.—fraction
ft.—foot, feet
gm.—gram, grams
H—hydrogen
Improv—improvements
in.—inch, inches
Inc.—Incorporated
insol.—insoluble
Is.—Island
lb.—pound, pounds
Lk., lk.—Lake, lake
Loc—location
Ltd.—Limited
max.—maximum
mi.—mile, miles
min.—minimum
Mo—molybdenum
Mt.—Mount
mtn.—mountain
N.—north
NE.—northeast
no.—number
Nos.—Numbers
NW.—northwest
O—oxygen
Ore min—ore mineral(s)
oz.—ounce, ounces
p.—page
Pb—lead
%—percent
pp.—pages
Prod—production
Prop—property
R.—river, range
Ref—references
Ry.—railway
S.—south
S—sulfur
SE.—southeast
sec.—section
sq.—square
SW.—southwest
T.—township
tr.—trace
U—uranium
U. S.—United States
vol.—volume
W—tungsten
W.—west
Wash.—Washington
yd.—yard, yards
yr.—year, years
Zn—zinc

Sec. 6, (25-15E). The parenthetical abbreviation indicates Township 25 North, Range 15 East, Willamette meridian.

(1950——) This parenthetical abbreviation after the name of a mining property owner indicates the date he acquired the property and that he was still in possession of it at the time of the writing of this report.

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LIST OF WASHINGTON MOLYBDENUM OCCURRENCES

CHELAN COUNTY

Crown Point (Aurelia Crown, Crown Power) (1)

(See p. 23 for description.)

Holden (Howe Sound, Irene) (2)

Jack Creek (6)

Keefer Brothers (4)

Merritt (Smith) (5)

Robischaud (Safety Harbor Creek, Copper King) (3)

(See p. 25 for description.)

FERRY COUNTY

Abe Lincoln (7)

Loc: Near N. line SE¼ sec. 26, (30-32E), Keller dist. **Ore:** Copper, lead, zinc, molybdenum. **Ore min:** Pyrite, chalcopyrite, galena, sphalerite, molybdenite. **Deposit:** 6-in. quartz vein in which sulfides are distributed in bands. Seams in wall rock coated with films of molybdenite and pyrite. **Dev:** 40-ft. adit. **Ref: 122,** p 126.

Addie B (10)

Barstow (Lucky Five and Lakeview) (2)

Loc: Sec. 36, (38-36E), on Boulder Cr., 8 mi. N. of Boyds. **Access:** 2 mi. from railroad. **Prop:** 21 claims. **Owner:** Dayton Stewart and Joe Dilly, Spokane, Wash. (1942). **Ore:** Molybdenum. **Deposit:** Drill holes spaced as much as 2,000 ft. apart are said to have encountered molybdenum in amounts as high as 13%. **Dev:** 12 drill holes 8 to 10 ft. deep. **Assays:** Samples from 12 holes said to av. 1% Mo. **Ref: 157. 158. Note:** Former owner states that the reported molybdenite has been proven to be graphite.

Big Chief (Apex, Chief) (4)

California (12)

(see also Consolidated Mines and Smelting Co., Ltd.)

Loc: NW¼ sec. 5, (29-33E), Keller dist. **Elev:** 1,900 ft. **Prop:** Several unpatented claims. Part of Consolidated Mines and Smelting Co., Ltd. property. **Owner:** Consolidated Mines and Smelting Co., Ltd., Wenatchee, Wash. (1950——). Central

Mining Co. (1915). **Ore:** Copper, silver, molybdenum. **Ore min:** Pyrite, chalcopyrite, molybdenite, chalcocite, malachite, molybdic ocher, powellite. **Deposit:** Numerous sparsely mineralized quartz veinlets in granite. Molybdenite occurs in seams widely scattered in the wall rock. **Dev:** 40-ft. adit (Caledonia), several other short adits and open cuts. **Assays:** Sample representative of several feet of the material exposed in the adit assayed 1% Cu, 2.2 oz. Ag. **Ref: 122,** p. 120. **158.**

Clay (8)

Cold Spring (3)

Loc: NE¼ sec. 23, NW¼ sec. 24, SW¼ sec. 13, (32-36E), Covada dist. **Elev:** 1,000 ft. **Prop:** 7 patented claims: Cold Spring, Fairview, Little Grouse, Anchor, F. and M., Mary, and one other. **Owner:** Glen L. and James Brink, Wenatchee, Wash. (1948). **Ore:** Lead, copper, zinc, molybdenum. **Ore min:** Molybdenite, pyrite, chalcopyrite, galena, sphalerite. **Deposit:** Narrow crooked quartz vein at contact of mica schist and biotite feldspar porphyry. Also a mineralized silicified shear zone 15 ft. wide in mica schist. **Dev:** 300-ft. adit from which a 100-ft. drift has been driven. **Ref: 46,** p. 120. **122,** p. 172. **158.**

Consolidated Mines and Smelting Co., Ltd. (12 and 14)
(see also Iconclast and California)

Loc: Sec. 5, (29-33E), secs. 35 and 36, (30-33E), and secs. 12 and 13, (36-32E), Keller dist. **Access:** Roads. **Prop:** Includes Golden Cord, Advance, Silver Ridge, Iconclast, California properties. **Owner:** Consolidated Mines and Smelting Co., Ltd., Wenatchee, Wash. (1952——). **Ore:** Copper, silver, gold, molybdenum, lead, zinc. **Deposit:** At main property a mineralized fracture zone in granite shows strong silification with scattered rhodochrosite and pyrite, also seams of chalcopyrite and galena and rarely molybdenite along joints and slips. Zone is exposed for 2,500 ft. in length, 200 ft. in width, 700 ft. in depth, and is reported to carry scattered low values. **Dev:** Several thousand feet of underground workings in many separate adits. **Ref: 28,** pp. 67-71. **97,** 1938, p. 566; 1939, p. 618. **108,** 10/39, p. 32. **150,** p. 29. **158.**

Great Western (6)

Handspike (13)
(see also Walla Walla)

Loc: Near center NE¼ sec. 5, (29-33E), Keller dist. **Elev:** 1,800 ft. **Prop:** 1 claim of Walla Walla group. **Owner:** Walla Walla Copper Mining Co. (1915-1924). **Ore:** Copper, molybdenum. **Ore min:** Pyrite, chalcopyrite, molybdenite. **Gangue:** Quartz, sheared granite. **Deposit:** 3-ft. lode of sheared altered granite partly replaced by quartz and ore minerals. **Dev:** 150-ft. adit. **Ref: 98,** 1918-1925. **112,** p. 209. **122,** p. 118.

Iconoclast (14)

(see also Consolidated Mines and Smelting Co., Ltd.)

Loc: Near center NE¼ sec. 6, (29-33E). **Elev:** 2,450 ft. **Access:** 1¾ mi. NW. of Keller by road. **Prop:** Several unpatented claims. Part of Consolidated Mines and Smelting Co., Ltd. property. **Owner:** Consolidated Mines and Smelting Co., Ltd., Wenatchee, Wash. (1940——). Iconoclast Gold & Copper Mining Co. (1902). Iconoclast Consolidated Mines Co. (1908-1918). Tenas Mining Co. (1918-1926). **Ore:** Copper, silver, gold, molybdenum. **Ore min:** Pyrite, chalcopyrite, molybdenite, malachite. **Gangue:** Quartz. **Deposit:** A zone of severely sheared, crushed, bleached, and sericitized granite contains a network of minute mineralized quartz veinlets. Surface indications are that the zone is 150 ft. wide and ¼ mi. long. **Dev:** 250-ft. adit from which a 50-ft. drift and 125-ft. crosscut have been driven. **Assays:** Low-grade ore. Richest portions contain est. 5% pyrite and chalcopyrite together. Sample taken across 60-ft. outcrop assayed tr. Au, 0.4 oz. Ag. **Ref: 122,** pp. 120-121. **158.**

Illinois (Oregon) (15)

Loc: SW¼ sec. 5, (29-33E), ½ mi. S. of the California group, Keller dist. **Elev:** 2,100 ft. **Prop:** Several claims. **Owner:** Illinois Copper & Silver Mining & Milling Co. (1915-1926). Illinois Mining & Milling Co. (1908). **Ore:** Copper, molybdenum, zinc, lead, gold, silver. **Ore min:** Pyrite, chalcopyrite, molybdenite, galena, spahlerite. **Gangue:** Quartz, calcite. **Deposit:** Irregular veins and bunches of mineralized quartz in granite and schist. Also sparsely disseminated ore minerals. **Dev:** 500-ft. adit. **Assays:** Body as a whole is low grade. **Ref: 33,** 1908, p. 804. **58,** p. 32. **98,** 1918-1926. **112,** p. 183. **116,** no. 4, 1908, p. 91; no. 5, 1908, p. 117. **122,** pp. 121-122.

Jumper (16)

(see also Walla Walla)

Loc: Near center NE¼ sec. 5, (29-33E). 700 ft. NW. of Handspike, Keller dist. **Elev:** 2,000 ft. **Prop:** 1 claim of Walla Walla group. **Owner:** Walla Walla Copper Mining Co. (1915-1924). **Ore:** Copper, silver, zinc, molybdenum. **Ore min:** Chalcopyrite, pyrite, sphalerite, molybdenite, malachite, copper sulfate. **Gangue:** Quartz. **Deposit:** A 3-ft. lode composed largely of altered granite, but quartz veinlets containing finely divided sulfides are numerous and closely spaced. **Dev:** Open cut. Assays: A lenticular mass 6 in. wide from footwall of the lode assayed 7.5% Cu and 11.4 oz. Ag. Test sample of 1 ton of ore is said to have yielded $39 in Cu and Ag. **Ref: 98,** 1918-1925. **112,** p. 209. **122,** pp. 118-119.

Kelly Camp (1)

Meadow Creek (King Richard, Blevins, San Poil Monitor) (9)
(See p. 26 for description.)

Mount Tolman (Meadow Creek) (11)

Polepick (17)

Rosario (5)

Schminski (19)

Loc: Secs. 1 and 2, (28-33E), 3 mi. N. of Hellgate Rapids, Keller dist. **Owner:** E. Schminski (1913). **Ore:** Molybdenum (gold and silver have been reported, but apparently erroneously). **Ore min:** Molybdenite. **Gangue:** Quartz, feldspar. **Deposit:** Molybdenite distributed in widely scattered tiny patches in pegmatite enclosed in granite. **Dev:** Several thousand feet of work, distributed among several adits. **Assays:** Gold assays reported to be consistently nil. **Prod:** None. **Ref: 122,** pp. 108, 139. **130,** p. 82. **141,** p. 96. **158.**

Walla Walla (18)
(see also Handspike, Jumper)

Loc: NE¼NE¼ sec. 5, (29-33E), Keller dist. **Elev: 1,700 ft. Prop:** 1 of several claims in Walla Walla group. **Owner:** Walla Walla Copper Mining Co. (1915-1924). **Ore:** Copper, lead, zinc, molybdenum, gold. **Ore min:** Pyrite, chalcopyrite, sphalerite, galena, molybdenite. **Gangue:** Quartz, sericite. **Deposit:** Sheared sericitized granite sparsely mineralized, and mineralized quartz veinlets which have been severely crushed. **Dev:** 635-ft. adit from which a 75-ft. crosscut has been driven (known as Surprise adit). **Ref: 122,** pp. 117-118.

GRANT COUNTY

Electric City (Big Four, Daniels, Black-Rosauer) (1)

Loc: Sec. 14, (28-30E), ½ mi. E. of Electric City, at foot of E. wall of Grand Coulee. **Prop:** 4 claims. **Owner:** Black-Rosauer Mines, Inc. (1937). Big Four Mining Co. **Ore:** Molybdenum, silver, gold. Bismuth, beryllium reported. **Ore min:** Molybdenite, pyrite, pyrolusite. **Gangue:** Quartz, fluorite. **Deposit:** Pegmatitic lenses of mineralized quartz as much as 10 ft. thick in granite. **Dev:** 100-ft. shaft, several cuts, pits, shallow shafts, and short adits. **Assays:** Probably less than 1% MoS_2. Owner states \$5.00 Au, \$3.00 Mo. One sample showed 0.13% Mo, 1.90 oz. Ag, and no Bi, Be, or Au. **Ref: 111,** p. 9, **157.**

KING COUNTY

Bear Basin (2)

Clipper (Katie Belle) (5)
(See p. 28 for description.)

Devils Canyon (3)
(See p. 29 for description.)

Goat Mountain (4)

Lost Lode (6)

Monte Carlo (1)

LEWIS COUNTY

Eagle Peak (1)

LINCOLN COUNTY

Spokane Molybdenum (Pitney Butte, Egypt) (1)
(See p. 31 for description.)

OKANOGAN COUNTY

American Graphite (32)

Loc: Mine in sec. 27, (34-29E). Mill in sec. 29, (34-27E). **Access:** Road. **Prop:** 70 claims and 179 acres of land. **Owner:** American Graphite & Metals Corp. (1948). **Ore:** Graphite with some gold and molybdenum. **Ore min:** Graphite, molybdenite. **Deposit:** Graphite schists and graphite-bearing crystalline limestone. **Dev:** Adit, shaft. **Improv:** Mill, cabins, bunker (1949). **Assays:** Assays indicate $2.00 Au in some samples. Spectrographic analysis shows the presence of 0.31% MoS_2. **Ref: 158. Note:** This property, originally thought to be a molybdenum prospect, was proven to have values principally in graphite, and to have but little molybdenum.

Bi-Metallic (17)
(See p. 34 for description.)

Billy Goat (2)

Loc: Near SE. cor. sec. 15, (38-20E), on S. slope of Billy Goat Mtn., NW. of Winthrop. **Elev:** 4,500 to 5,300 ft. **Access:** Road up Eightmile Cr. 80 mi. from railroad at Pateros. **Prop:** 4 claims: Billy Goat and Billy Goat Nos. 2 to 4. **Owner:** W. F. Berge, R. E. Johnson, Clint Hanks, Fred Hasse, and Mrs. Charles (Della) Graff (1946). **Ore:** Copper, gold, silver, zinc, molybdenum, lead. **Ore min:** Molybdenite, pyrite, chalcopyrite, sphalerite, galena, tetrahedrite. **Gangue:** Quartz, ankerite. **Deposit:** Mineralized quartz veinlets ¼ in. to 2 in. wide lace through altered volcanic rock. A large area is mineralized. **Dev:** 3 shafts 20, 40 and 60 ft. deep; 3 adits 60, 15 ft., and one of unknown length; and a 700-ft. drift. **Assays:** Copper generally less than 1% but in places as much as 2% over minable widths. Gold also low but as much as 0.5 oz. per ton in places. **Ref: 46,** p. 176. **104,** 8/30/34, p. 22. **106,** 7/34. **158.**

Carr (3)

Loc: Secs. 14 and 15, (38-20E), adjacent to Billy Goat prospect. **Access:** Road up Eightmile Cr. **Prop:** 4 unpatented claims. **Owner:** Ralph Kennison, Winthrop, Wash. (1946). **Ore:** Copper, gold, silver, lead, zinc, molybdenum. **Ore min:** Pyrite, chalcopyrite, sphalerite, galena, molybdenite. **Deposit:** Fractured and silicified volcanic rock containing mineralized stringers. **Dev:** 2 adits 10 to 20 ft. long. **Assays:** Similar to those of the Billy Goat. **Ref: 158.**

Corson (25)

Dutch John (Sherwood, Lodge, Texas Creek) (28)
(See p. 45 for description.)

Eagle (18)

Four Metals (9)

Frankie Boy (22)

Golden Chariot (12)

Golden Zone (8)

Green Lake (24)

Loc: SW¼NW¼ sec. 13, (34-25E), about 1 mi. W. of Green Lk. **Ore:** Molybdenum. **Ore min:** Molybdenite. **Deposit:** Quartz vein containing molybdenum. **Ref: 158.**

Hanks (4)

Loc: Near NW. cor. sec. 23, (38-20E), adjacent to Billy Goat prospect. **Elev:** 4,600 to 4,700 ft. **Access:** Road up Eightmile Cr. **Prop:** 3 unpatented claims. **Owner:** Clint Hanks, Winthrop, Wash. (1946). **Ore:** Copper, gold, silver, lead, zinc. **Ore min:** Pyrite, chalcopyrite, sphalerite, galena, molybdenite. **Gangue:** Quartz. **Deposit:** Similar to that of Billy Goat prospect. Small mineralized quartz veinlets in a wide area of altered volcanic rock. **Dev:** Two adits 20 to 30 ft. long and several open cuts. **Improv:** Cabins (1946). **Ref. 158.**

Holden-Campbell (30)

Loc: Mainly secs. 10 and 11, (30-22E). Also along S. edge of secs. 2, 3, and 4, and N½ sec. 14. **Elev:** 3,000 ft. **Access:** Easily accessible from Methow highway by 4 mi. of road up Squaw and Grubstake Creeks. **Prop:** 29 claims. **Owner:** S. J. Holden and A. C. Campbell, Chelan, Wash. (1943). **Ore:** Gold, copper, tungsten. **Ore min:** Pyrite, chalcopyrite, molybdenite, scheelite. **Deposit:** Quartz veins in gneissoid diorite, among them the Hunter, the Okanogan, the Doris Barbara, the Bay Horse, the Ace of Diamonds, and the Esther veins. **Dev:** More than 1,100 ft.

of underground workings and several surface cuts. **Assays:** Est. 0.25% scheelite. **Prod:** Considerable gold ore. **Ref: 37,** pp. 45-47. **63,** p. 87. **158.**

Hoot Owl (31)

Loc: NE¼ sec. 22, (34-29E), Park City dist. **Owner:** Molybdenum Mines Co. (1934-1937). **Ore:** Molybdenum, gold. **Gangue:** Calcite, quartz. **Deposit:** 100-ft. mineralized zone. **Assays:** 0.02 oz. Au, 0.014% Mo, 3.43% graphite. **Ref: 97,** 1938, p. 566. **104,** 8/30/33, p. 18. **158.**

Horseshoe Basin (MacPhearson, Arnold Peak) (7)
(See p. 46 for description.)

Hudnut (Hudnutt) (36)

Independence (29)

Kaaba (Caaba, Kaaba-Texas) (11)

Loc: Secs. 13, 14, and 23, (40-25E). **Elev:** 1,500 ft. **Access:** 1 mi. S. of Nighthawk on macadam road. **Prop:** 27 claims, 7 of which are patented. Also 3 patented lots. **Owner:** Kaaba Silver-Lead Mines, Inc. (1948-1951). Mines Operating Co. (1918). Kaaba Mines Co. (1921-1926). General Metals Co., Ltd. (1929-1931). Kaaba-Texas Mining Co. (1938-1947). **Ore:** Lead, silver, zinc, copper, gold, tungsten. **Ore min:** Galena, chalcopyrite, sphalerite, molybdenite, pyrite, scheelite, marcasite. **Gangue:** Quartz, calcite, gouge. **Deposit:** Persistent but low-grade quartz vein av. 10 ft. in width along a lamprophyre-granite contact. Ore minerals banded along footwall and bunched on hanging wall. **Dev:** Inclined shaft 300 ft. long with 1,100 ft. of drifts on four levels, over half on third level. **Improv:** 150-ton flotation mill (1952). **Assays:** Ore milled from 1943 to 1946 av. $4.03 gross. Av. assay is 1.2% Pb, 0.5% Zn, 0.1% Cu, 2.25 oz. Ag. **Prod:** 1915, 1918, 1920, 1929. 95,045 tons of ore milled from 1943 to 1949, 1950. **Ref: 12,** p. 66. **13,** p. 108. **37,** pp. 34-35. **46,** pp. 216-219. **54,** p. 2. **63,** p. 101. **68,** p. 11. **97,** 1915, 1918, 1920, 1929, 1944-1949. **98,** 1920-1926. **106,** 7/2/31; 7/21/32. **108,** 6/42, p. 28. **112,** p. 192. **129,** pp. 228-231. **154,** p. 93. **158.**

Lady of the Lake (23)

Loc: NE¼ sec. 6, (35-25E), on S. extremity of Homestake Mtn. **Elev:** 2,350 ft. **Access:** ½ mi. E. of Conconully by road. 18 mi. by road to railroad at Okanogan. **Prop:** 2 claims: Lady of the Lake, Hidden Springs. **Owner:** Wm. P. Shirk, Spokane, Wash. (1951). Sie Walter leasing to J. E. Lindston (1942). **Ore:** Silver, copper lead, zinc, gold, tungsten. **Ore min:** Galena, pyrite, chalcopyrite, sphalerite, molybdenite, scheelite. **Gangue:** Quartz, calcite. **Deposit:** Sheared and fractured mineralized zones mostly 3 to 5 ft., but in places 20 ft. wide in fine-grained metamorphic rocks. Zones are principally vein quartz. **Dev:** 150-ft. adit, 50 ft. of drifts, several open cuts, a caved adit, and a 24-ft. adit below high-water level of Conconully Lk. **Assays:** 70 to 125 oz. Ag, 11% to 15% Pb, tr. Au. 13 samples across widths of 4 to 12 ft. gave weighted av. of 0.163% WO_3 and showed 0.02% to 0.06% Cu, 0.1% to 0.3% Pb, 0.1% to 0.4% Zn, 0.02% to 0.06 % Mo. **Ref:** **12,** p. 58. **13,** p. 92. **37,** pp. 43-44. **75,** p. 29. **157. 158.**

Malott (26)

Loc: SE¼SW¼ sec. 22, (32-25E), NE. of Malott. **Access:** 10 mi. by road from railroad at Monse. **Owner:** Phillip Bedard and John Burns, Okanogan, Wash. (1942). **Ore:** Copper, zinc, molybdenum, nickel. **Ore min:** Pyrite, pyrrhotite, chalcopyrite, sphalerite, molybdenite. **Gangue:** Quartz, feldspar. **Deposit:** Knolls of quartz and pegmatite surrounded by granite. One zone in the pegmatite mineralized for at least 12 ft. in length. **Dev:** 4 adits and open cuts. **Assays:** 2 channel samples each 4 ft. long showed 0.14% and 0.15% Mo. **Prod:** 200 to 300 lb. of sulfide ore on the dump. **Ref: 157. 158.**

Mineral Hill (Washington Consolidated, Seven Devils) (21)

Molly (Luke) (6)

Moncosilgo (Adams) (14)

Loc: NE¼SE¼ sec. 20, NW¼SW¼ sec. 21, (40-27E), about 1 mi. NW. of Oroville. **Elev.** 1,650 ft. **Access:** 2 mi. by road from railroad at Oroville. **Prop:** 120 acres deeded land. **Owner:** C. S. Adams, W. J. Ripley, J. E. Stuible, Oroville, Wash. (1943——). **Ore:** Copper, gold, silver. **Ore min:** Chalcopyrite, bornite, cuprite, pyrite, pyrrhotite, native copper, molybdenite, scheelite. **Gangue:** Quartz, calcite. **Deposit:** Disseminations and small veinlets in silicified bands in diorite. Mineralized zone exposed for 200 ft. along strike. **Dev:** 56-ft. adit, 10-ft. drift, open cuts. **Assays:** Tr. to 0.05 oz. Au, 0.10 to 2.32 oz. Ag, 0.51% to 10.6% Cu. No commercial W. **Ref:** **37,** p. 31. **157.**

O. K. (13)

Pioneer

Rustler (27)

Sheep Mountain (Molly, Dodd, Jim Dodd, Boundary) (1)
(See p. 48 for description.)

Spokane (American Rand) (15)

Loc: Near center E½ sec. 10, (39-26E), above NW. shore of Wannacut Lk. **Access:** Good road from Oroville to the mine. **Prop:** 13 patented and 3 unpatented claims. **Owner:** American Rand Corp. (1935-1938). Morgan Mines Co. (1916-1918). Oroville Gold Mining Co. (1934). **Ore:** Gold, silver, lead, copper, molybdenum. **Ore min:** Pyrite, galena, chalcopyrite, molybdenite, reportedly free gold. **Deposit:** Quartz vein 15 in. wide in argillite a short distance above a granite contact. Ore minerals occur in fractures in the quartz. Pyrite disseminated in the wall rock. **Dev:** 100-ft. inclined shaft from which short drifts have been driven. **Assays:** Ore from adit: 8 oz. Au, 2 oz. Ag; from shaft: 7.5 oz. Au, 2 oz. Ag; from dump: 7.5 oz. Au, 2.5 oz. Ag. 1.05% molybdenum reported. **Prod:** 1916-1918, 1935-1938. **Ref:** **12,** p. 66. **13,** p. 104. **63,** pp. 99-100. **97,** 1916-1918, 1935, 1937, 1939. **104,** 2/15/35, p. 23; 6/30/36, p. 25. **154,** p. 98. **158.**

Starr (Silver Tip) (19)

(See p. 51 for description.)

Sterling (34)

Loc: NW¼SE¼ sec. 8, (31-30E). **Access:** 6 mi. NW. of Nespelem. Road for 4 mi. at least. **Prop:** 1 claim: Sterling. **Ore:** Molybdenum. **Ore min:** Molybdenite, pyrite, limonite. **Deposit:** 15-ft. quartz vein contains sparsely disseminated flakes of molybdenite and pyrite. **Dev:** Small shaft, open cuts. **Assays:** Appears to be barren of Cu, Pb, Zn minerals. **Ref: 122,** p. 79.

Summit (10)

Swayne (5)

Tonasket (Montgomery, Fluorspar) (20)

Triune (Crescent) (16)

Twin Pine (35)

Wasco (33)

Loc: Near center S½ sec. 9, (33-31E), Park City dist. **Elev:** 3,900 ft. **Prop:** Several claims. **Owner:** May be property held by West King Mining Co. **Ore:** Silver, copper, gold, lead, zinc, molybdenum. **Ore min:** Galena, sphalerite, chalcopyrite, pyrite, tetrahedrite, molybdenite, molybdite, malachite, azurite. **Gangue:** Quartz, fluorite. **Deposit:** Three quartz veins, 12 in., 24 in., and 36 in. wide, in granite and along its contact with schist are sparsely mineralized. The molybdenite occurs in granitic dikes. **Dev:** Shallow shaft, several small surface cuts, 400-ft. adit. **Assays:** Ores said to contain appreciable quantities of Ag and Cu and some Au. **Ref: 7,** pp. 209-210. **46,** pp. 178-179. **122,** pp. 100-101.

PEND OREILLE COUNTY

Coffin (2)

Little Noisy (3)

Molybdenite Mountain (4)

Loc: Sec. 18, (37-44E), Metaline dist. **Access:** 6 mi. by trail. **Prop:** Several unpatented claims. **Owner:** Abandoned (1941). Empire Molybdenite Mining & Milling Co. (1918-1922). Molybdenum Mining & Milling Co. (1925). **Ore:** Molybdenum. **Ore min:** Molybdenite, pyrite. **Deposit:** A quartz vein 3 ft. wide and exposed for a length of 40 ft. is sparsely mineralized with molybdenite and pyrite. **Dev:** 40-ft. adit, open cuts. **Prod:** \$6,000 prior to 1916. **Ref. 29,** p. 52. **98,** 1922-1926. **105,** 1916, p. 387. **112,** p. 178. **116,** no. 11, 1907, p. 7.

Polly Molly (1)

PIERCE COUNTY

Golden Rule (1)

White River

SKAGIT COUNTY

North Coast (Bornite) (2)

Skagit Queen (British) (3)

Thunder Creek

Loc: On Thunder Cr., a headwater tributary of Skagit R. **Ore:** Molybdenum. **Ore min:** Molybdenite. **Deposit:** Said to be a promising deposit. **Note:** Investigation in this area by the Division of Geology (1940) did not reveal any molybdenite. **Ref: 130,** p. 82. **141,** p. 96.

Washington (1)

SKAMANIA COUNTY

Miners Queen (Columbia Gold and Copper) (1)

Loc: N½ sec. 4, (3-5E), on Miners Cr., Washougal dist. **Access:** 4½ mi. by road from Sunset Ranger Station. **Prop:** 7 claims. **Owner:** J. W. McMahon, Portland, Ore. (1950——). **Ore:** Copper, molybdenum. **Ore min:** Chalcopyrite, magnetite, malachite, molybdenite, pyrite. **Gangue:** Quartz, tourmaline, sericite. **Deposit:** An area about 80 by at least 140 ft. in which are small discontinuous veinlets and disseminations of copper and molybdenum sulfides in altered diorite. **Dev:** 6 short adits, 30-ft. shaft, a deeper shaft. **Assays:** 5% to 10% Cu reported. **Ref: 157. 158.**

Spirit Lake

SNOHOMISH COUNTY

Armament (Wayside) (17)

Loc: NW¼ sec. 30, (28-11E). **Access:** 7½ mi. from railroad at Index by road along the E. side of the N. Fk. of Skyhomish R.

Prop: 1 claim: Armament No. 1. **Owner:** Karl and Karin Elizabeth Paykull, Seattle, Wash. leasing from R. M. Brown, Pheom and Marjorie Boyle (1942-1949). Robert McDonald and John J. Cashier (1942). **Ore:** Molybdenum, copper. **Ore min:** Molybdenite, chalcopyrite, pyrite, molybdite, scheelite, malachite. **Gangue:** Quartz and altered diorite. **Deposit:** Stockwork in gneissoid quartz diorite of short discontinuous quartz veinlets containing molybdenite and chalcopyrite. The ore body has exposed dimensions of 120 ft. by 140 ft. by a 20-ft. depth, but its limits are not known. Veinlets up to 3 in. wide and mostly at least 6 in. apart. **Dev:** Several small open cuts and 2 road cuts. **Assays:** Three 10-ft. channel samples from the better ore showed 0.06%, 0.24%, 0.11% MoS_2; 0.15%, 0.30%, 0.36% Cu. **Ref: 14,** p. 16. **158.**

Copper Lake (6)
(See p. 63 for description.)

Glacier Peak (Calumet) (4)
(See p. 63 for description.)

Golden Eagle (14)
(See p. 64 for description.)

Hustler (7)

Iowa (Mint) (10)

Loc: NW¼ sec. 27, (29-10E), Sultan dist. **Elev:** 2,550 to 2,895 ft. **Access:** Truck road along N. Fk. Sultan R. crosses the property. **Prop:** Mint and Mint No. 1 claims. **Owner:** Sultan Basin Mining Co., Sultan, Wash. (1940-1945). Iowa Mining Co. (1915). **Ore:** Copper, gold, silver. **Ore min:** Chalcopyrite and small amounts of scheelite, powellite, molybdenite, sphalerite, bornite, malachite. **Gangue:** Quartz, calcite, chlorite. **Deposit:** Mineralized fracture zones in diorite and metamorphic rocks. Zones vary in width from 2 or 3 in. to 48 in. One lens of ore 16 to 22 in. thick. **Dev:** 3 adit levels comprise more than 1,000 ft. of underground workings. **Assays:** 104 tons of ore av. 20% Cu, 0.223 oz. Au, 3.23 oz. Ag. 43 tons of ore av. 14.68% Cu, 0.06 oz. Au, 310 oz. Ag. **Prod:** 104 tons of ore prior to 1937. 96 tons 1937-1941. **Ref: 14,** p. 47. **23,** pp. 63-65. **37,** p. 56. **97,** 1915, p. 573; 1938, p. 459; 1941, p. 475. **158.**

Kromona (Scriber, Jones) (16)

Loc: Near center sec. 13, (28-9E), in Sultan Basin. **Elev:** 2,500 to 5,000 ft. **Access:** 5 mi. from Olney Pass by road. About 19 mi. from railroad at Sultan. **Prop:** 8 claims, 5 millsites. **Owner:** Kromona Mines Corp., Seattle, Wash. (1937——). Kromona Mining & Smelting Co. (1916-1937). **Ore:** Copper, silver, gold, molybdenum, tungsten. **Ore min:** Chalcopyrite, pyrite, pyrrhotite, molybdenite, scheelite, powellite, marcasite, bornite, malachite. **Gangue:** Quartz, calcite, shattered wall rock. **Deposit:** Shear zone across the contact of quartz diorite and old metamorphic rocks. Ore in places is slightly radioactive. **Dev:** 800-ft. adit with 225-ft. drift at 3,500-ft. elev., and a 58-ft. drift at 3,800 ft. Natural cave called the "Bear Cave" exposes vein on opposite side of ridge. **Improv:** Tram, 100-ton mill, bunkhouse (1952). **Assays:** 7 old assays show 1.4% to 38.4% Cu, 1.2 to 18.2 oz. Ag, 0.05 to 2.0 oz. Au. Later information indicates av. to be 2% to 4% Cu, 1 to 2 oz. Ag, $2 to $4 Au. A 4,860-lb. test shipment in 1952 showed 0.58 oz. Au, 1.76 oz. Ag, 12.81% Cu. **Prod:** 4,860-lb. test shipment in 1952 gave net smelter return of $138.06. 1954. **Ref: 14,** p. 48. **23,** pp. 75-78. **37,** p. 56. **98,** 1918-1926. **104,** 4/30/34, pp. 21-22. **106,** no. 2, 1920, pp. 4-5; 9/1/28. **112,** p. 187. **117,** no. 14, 1922, p. 5. **129,** pp. 293-296. **133,** p. 36. **158.**

Martin Engdahl (13)

Mineral Center (Bonanza, Edison, Louise, Washington-Iowa) (12)

Molly (18)

Loc: Sec. 30, (28-11E), near Galena Lookout Station. Approx. 9 mi. E. of Index on N. Fk. of Skykomish R. **Owner:** Wm. C. Duncan, 716 23rd Ave., Seattle 22, Wash. (1951). **Ore:** Uranium, molybdenum. **Ore min:** Molybdenite, uraninite, chalcopyrite. **Ref: 157.**

Nesta (3)

Loc: Sec. 34, (32-9E), about 3 mi. S. of Darrington, on Jumbo Mtn. **Elev:** 800 to 3,900 ft. **Access:** Within 1 mi. of good county road. **Prop:** 25 claims. **Owner:** Ole and Pete Nesta, Darrington, Wash. (1950). **Ore:** Copper, gold, silver, molybdenum, lead, zinc. **Ore min:** Pyrite, sphalerite, galena, molybdenite. **Deposit:** 10 veins from 2 to 10 ft. wide. Quartz veins 1 to 2 ft. thick in altered diorite. Molybdenum showings are small and scattered and only on the S. part of the claims. **Dev:** 12 adits aggregating 1,150 ft. **Improv:** Good cabin (1950). **Assays:** From $5 to $100 for hand samples. Av. values are very low. **Ref: 14,** p. 10. **111,** p. 6. **158.**

Rustler (8)

Loc: Sec. 11, (29-10E), in a deep canyon, Monte Cristo dist. **Ore:** Copper, molybdenum, lead, zinc. **Ore min:** Pyrrhotite, pyrite, chalcopyrite, molybdenite, galena, sphalerite. **Deposit:** Narrow pinching veins of quartz containing the sulfide minerals. A little molybdenite shows along seams of quartz in one adit. **Dev:** Several short adits and a shallow shaft. **Assays:** Est. 1% to 2% Cu over a width of 1 or 2 ft. In the shaft a 2-ft. width might av. 10% combined Zn, Pb, Cu. **Ref: 158.**

St. Theresa (15)

(See p. 65 for description.)

Silver Horseshoe (5)

Sultan King (Sultan Queen, Hicks) (11)

Sunrise (North Star, Oldfield) (1)

Loc: NE¼NE¼ sec. 29, (32-9E). **Access:** 5 mi. by road to railroad near Darrington. **Prop:** 4 claims. **Owner:** W. E. Oldfield, Seattle, Wash. (1951-1952). **Ore:** Gold, silver, copper, lead, zinc, molybdenum. **Ore min:** Chalcopyrite, galena, molybdenite, arsenopyrite, sphalerite, pyrite. **Gangue:** Quartz. **Deposit:** Narrow fractures cutting granite are filled with quartz and ore minerals. **Dev:** 2 adits aggregating 155 feet. **Assays:** 0.08 to 0.05 oz. Au, 1.3 to 9.1 oz. Ag, 0.8% to 1.67% Cu, 0.1% Mo, 9% As. **Ref: 14,** p. 10. **133,** p. 40.

Sunrise (9)

Loc: N. line sec. 15, (29-10E), near summit of Sunrise Mtn. **Elev:** 4,400 to 4,600 ft. **Access:** 2 mi. up Vesper Cr. by trail from Sultan Basin road, by which it is 26 mi. to railroad at Sultan. **Prop:** 4 unpatented claims: Wall Street, Occidental, Quaker City, Eldorado. **Owner:** George Startup, Startup, Wash., and Bob Curtis, Monroe, Wash. (1913-1943). **Ore:** Copper, gold, silver, molydenum. **Ore min:** Chalcopyrite, molybdenite, pyrrhotite, bornite. **Gangue:** Quartz, siderite, brecciated metamorphics. Quartzite and hornfels in which there are mineralized breccia and quartz veinlets extending outward from a pipe-like breccia mass 500 ft. or more in diameter and exposed to a depth of 350 ft. **Dev:** 45-ft. adit, 255-ft. adit, 35-ft. adit, 850-ft. adit, 3 open cuts. **Assays:** 2% to 4% Cu, 0.02 to 0.05 oz. Au, 0.4 to 4.8 oz. Ag from selected samples. Av. of deposit as a whole probably is less than 1% Cu, 0.02% Mo. **Ref: 14,** p. 50. **23,** pp. 68-70. **111,** p. 9. **158.**

Taylor and Nunn (Bergensen, Tum Tum) (2)

STEVENS COUNTY

American (2)

(See p. 65 for description.)

Chewelah Standard (Nellie S.) (14)

Columbia River (8)

Columbia Tungsten (Black Horse, Stockwell) (11)

Deer Trail Monitor (17)

(See p. 66 for description.)

Eagle (Blue Star, Redwood, Chewelah Eagle) (13)

Germania (18)

(See p. 67 for description.)

Germania Consolidated (Keeth, Industrial Tungsten, Norton) (19)

(See p. 70 for description.)

Juno-Echo (Western Molybdenum) (15)

(See p. 73 for description.)

Lawrence (Constitution, Judd) (3)

Loc: Sec. 21, (38-39E), E. of Phalen Lk. **Access:** Road. **Prop:** 4 unpatented claims. **Owner:** Joe Day and/or William Heritage, Colville, Wash. (1941). **Ore:** Molybdenum. **Ore min:** Molybdenite. **Gangue:** Quartz. **Deposit:** Small lenses or pockets of lean ore in granite near its contact with argillite. Argillite near contact contains molybdenite seams also. **Dev:** 100 ft. of workings in 3 adits, and several open cuts. **Ref: 30,** pp. 82-83. **158.**

Magma (Easy Money, Eldorado) (7)

Loc: E½SW¼ sec. 28, (38-41E), Northport dist. **Elev:** 3,200 ft. **Access:** Poor truck road from highway along S. Fk. Deep Cr. 14 mi. from railroad at Ione. **Prop:** 25 unpatented claims. **Owner:** Otto Berglund (Magma Molybdenum Mines Co.), Colville, Wash. (1921——). Magma Mines & Metals Co. (1930). **Ore:** Zinc, lead, molybdenum, tungsten, copper, silver, gold. **Ore min:** Sphalerite, galena, pyrite, molybdenite, scheelite. **Gangue:** Garnet, epidote, calcite. **Deposit:** Contact metamorphic replacement of limestone near its contact with granite. **Dev:** 610-ft. adit, 110-ft. shaft, and other workings total 1,800 ft. **Assays:** 5 tons handpicked galena av. 0.62% Pb. A composite of three 18-in. channel samples showed 0.3% Pb, 1.0% Zn, 0.11% WO_3, 0.22% Mo. **Prod.** 5 tons galena ore 1927. **Ref: 30,** p. 109. **37,** p. 63. **46,** p. 61. **97,** 1930, p. 676. **104,** 1/15/35, p. 25. **106,** 11/3/32, p. 9. **157. 158.**

New Leadville (Yo Tambien) (5)

Ray Cox Moly (4)

Rightside (Coyote, Gray Eagle, Koyotte, O'Neal-Schenk) (9)

Rocky Lake (10)

Loc: SE¼NE¼ sec. 34, (35-39E), Colville dist. **Access:** ¼ mi. from road by which it is 2 mi. to railroad at Arden. **Prop:** 8 unpatented claims. **Owner:** None (1949). Formerly owned by Ross Moorehead, Colville, Wash. **Ore:** Molybdenum, gold, silver, copper. **Ore min:** Molybdenite, pyrite. **Gangue:** Quartz. **Deposit:** Said to be an 8-ft. altered zone, traceable for 400 ft. in granite. Zone contains 30-in. quartz vein having sparsely scattered molybdenite and pyrite. **Dev:** 100-ft. inclined shaft, open cuts. **Ref: 30,** p. 51. **158.**

Sand Creek (20)

Short Wait (1)

Sierra Zinc (Aladdin, Blue Ridge) (6)

Tungsten King (16)

Washington Metals (12)

Western Molybdenum (Juno-Echo) (15)

(See p. 73 for description.)

WHATCOM COUNTY

Castleman

Midas (1)

Silver Creek (2)

(See p. 87 for description.)

Sulphide Creek (Shuksan) (3)

YAKIMA COUNTY

Bird (2)

(see also Copper Mining Co.)

Loc: NW¼ sec. 18, (15-12E), Bumping Lk. dist. **Elev:** 5,200 to 5,350 ft. **Access:** Truck road from Copper City. 70 mi. by road from Yakima. **Prop:** Bird, Bird Extension, and Red Bird claims. **Owner:** Copper Mining Co., Yakima, Wash. (1906——). **Ore:** Tungsten, copper. **Ore min:** Chalcopyrite, scheelite, molybdenite, arsenopyrite, pyrite. **Gangue:** Quartz, calcite. **Deposit:** Series of parallel and diverging quartz veinlets along a hydrothermally altered shear zone in granitic rock. Shear zone varies from seam up to 7 or 8 ft. wide and can be traced on surface for over 2,000 ft. **Dev:** Lower Bird 450 ft., Middle Bird 80 ft., Upper Bird 160 ft., Red Bird caved, 9 open cuts, and 2 shafts. **Assays:** Upper adit had av. of about 0.75% WO_3 for av. width of 3.3 ft. and length of 40 ft. Lower adit shows av. of about 0.1% WO_3, 3.5 ft wide for length of 150 ft. Better values at face of lower adit. **Prod:** 650 lb. of scheelite (63% WO_3) shipped in 1940 came mostly from Bird workings. **Ref:** **37**, pp. 79-81. **41**. **59**. **130**, pp. 84, 91. **141**, p. 109.

Chinook (1)

Copper Mining Co. (3)

(see also Bird)

Loc: Secs. 12 and 13, (15-11E) and secs. 7, 8, 17, 18, and 19, (15-12E), on Miners Ridge, Bumping Lk. dist. **Elev:** 4,000 to 6,000 ft. **Access:** 70 mi. by road to Yakima. **Prop:** 42 unpatented claims.

Owner: Copper Mining Co., Yakima, Wash. (1906——). **Ore:** Copper, tungsten, gold, silver, molybdenum. **Ore min:** Chalcopyrite arsenopyrite, molybdenite, scheelite, pyrite, bornite, malachite. **Gangue:** Quartz, tourmaline, calcite. **Deposit:** Mineralized quartz veins along shear zones in granite. Mineralization rather sparse. **Dev:** 3 Bird adits, Garibaldi adit, 2 New Find adits, Pasco adit, totaling more than 1,000 ft., numerous open cuts. **Assays:** Tr. Au, 0.60 to 2.00 oz. Ag, 1.15% to 3.35% Cu, tr. to 11.50% WO_3, 0.13% MoS_2. **Prod:** 1907; 11 tons copper conc. (1938); 650 lb. scheelite conc. (1941). **Ref: 9. 37,** pp. 79-84. **41. 59. 97,** 1937, p. 654; 1939, pp. 492, 618. **104,** 9/15/34, p. 25; 9/30/34, p. 22. **158.**

Crosetti (4)

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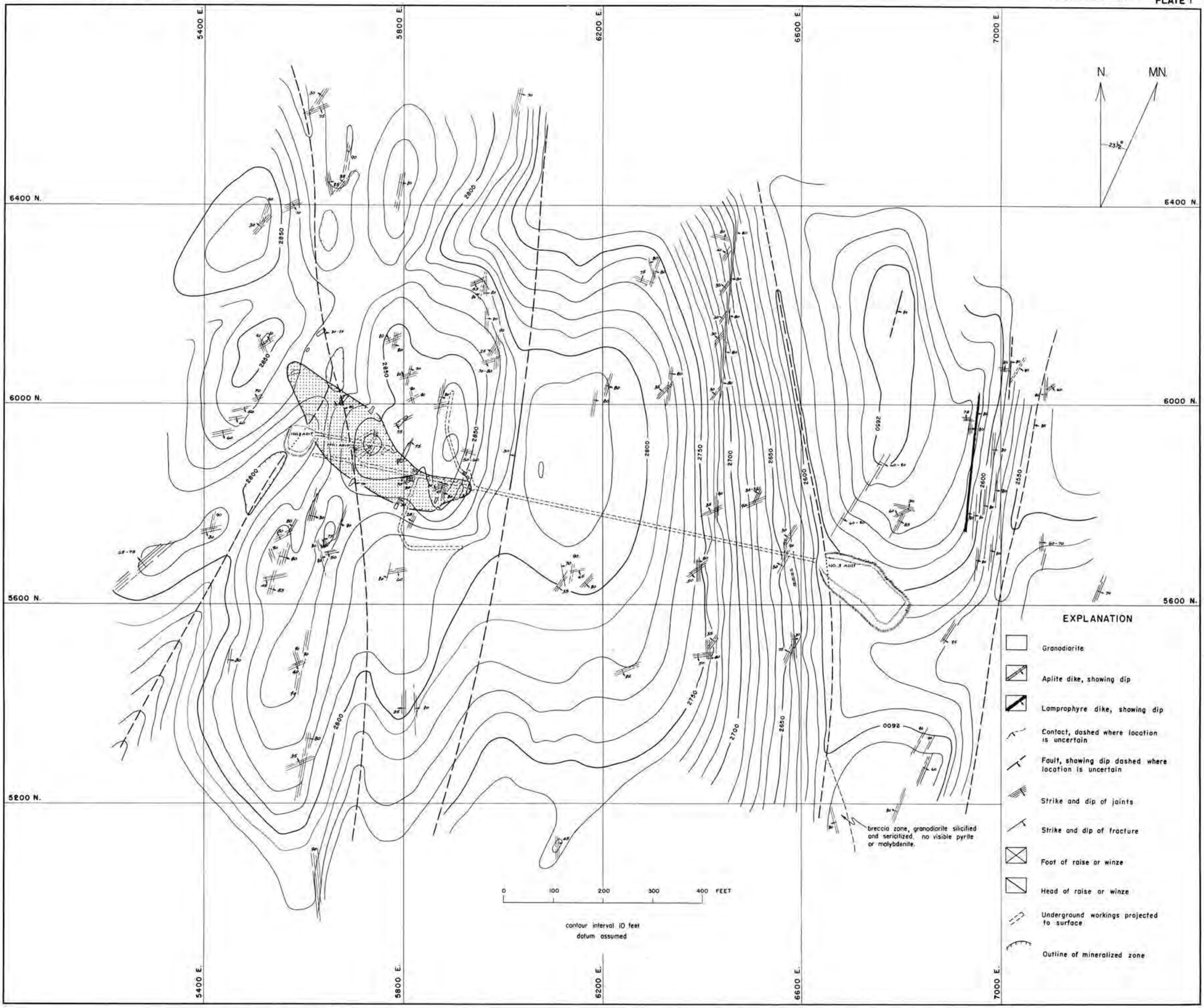
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

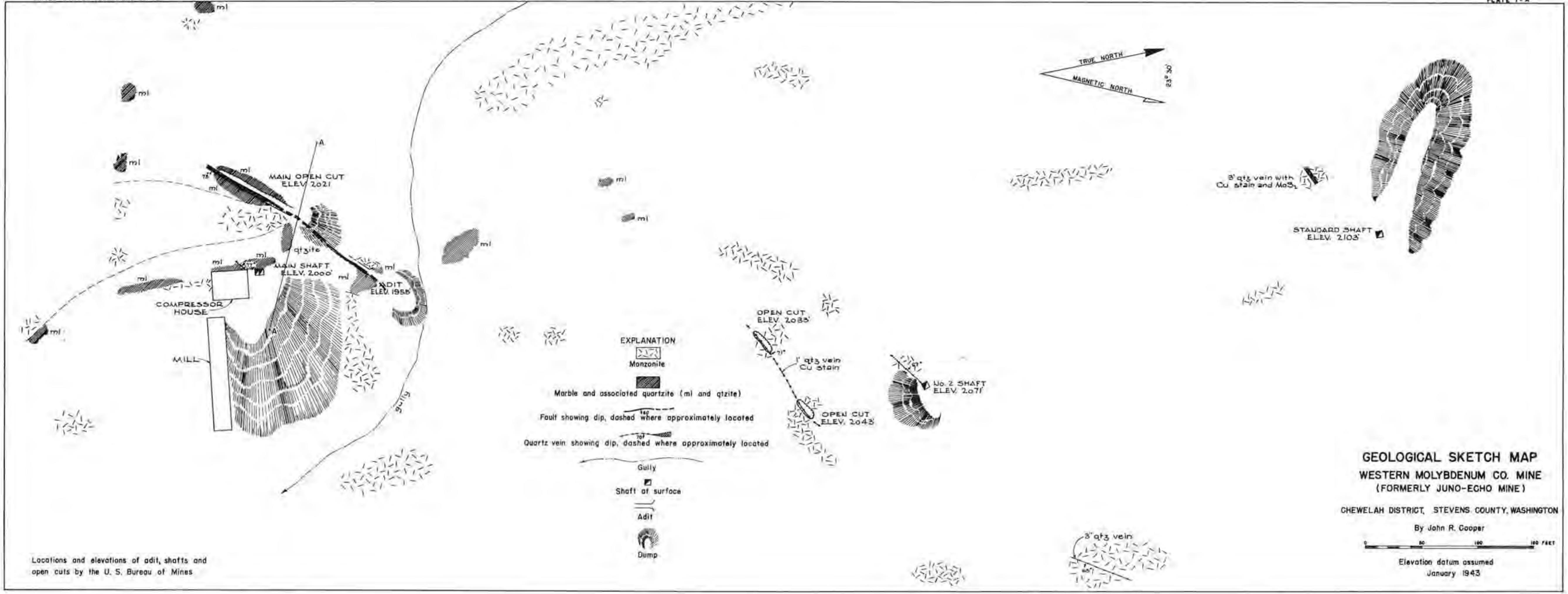
STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP
PLATE 1

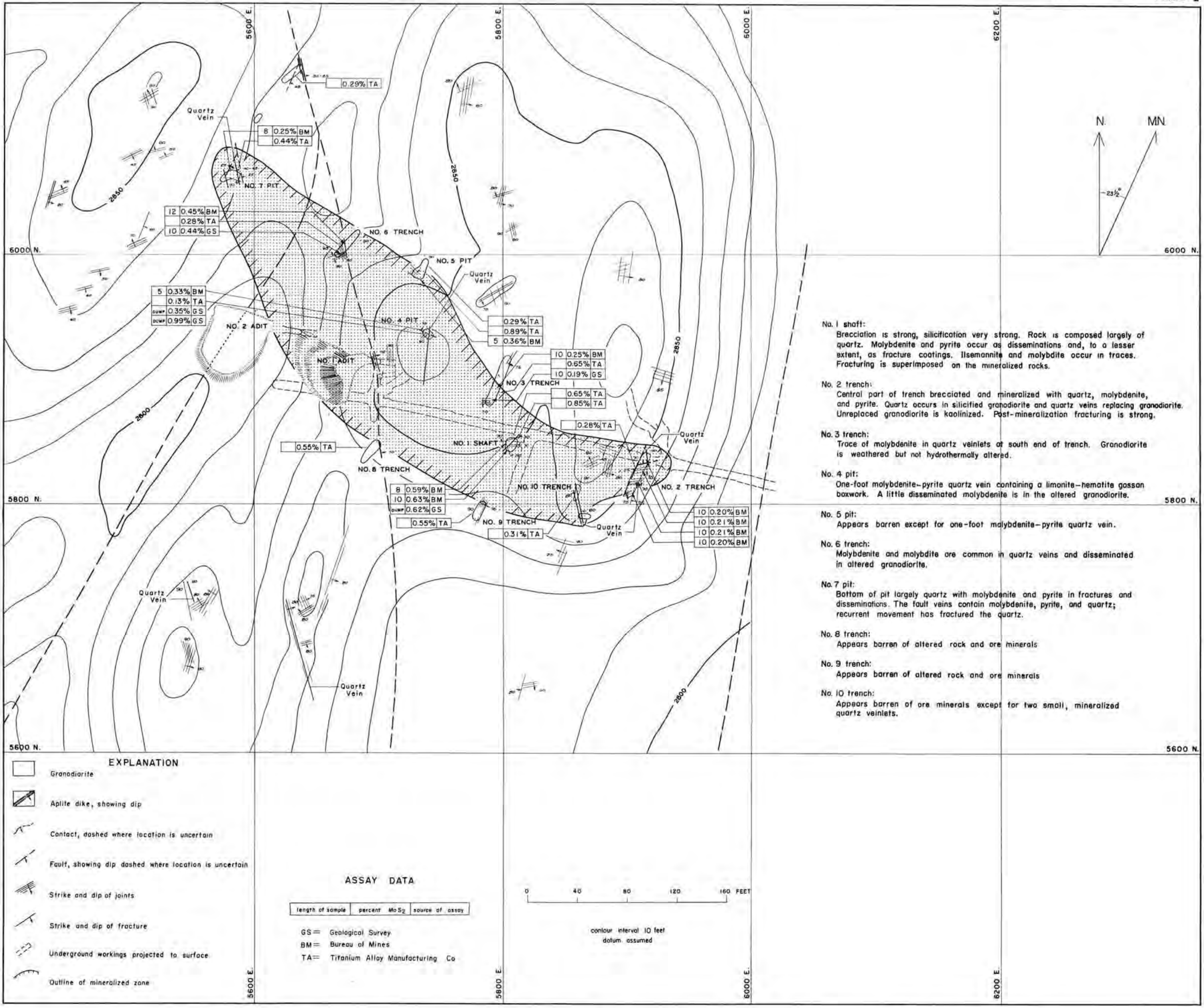


GEOLOGIC MAP OF STARR MOLYBDENUM MINE, OKANOGAN COUNTY, WASHINGTON

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PRELIMINARY MAP
PLATE I-A

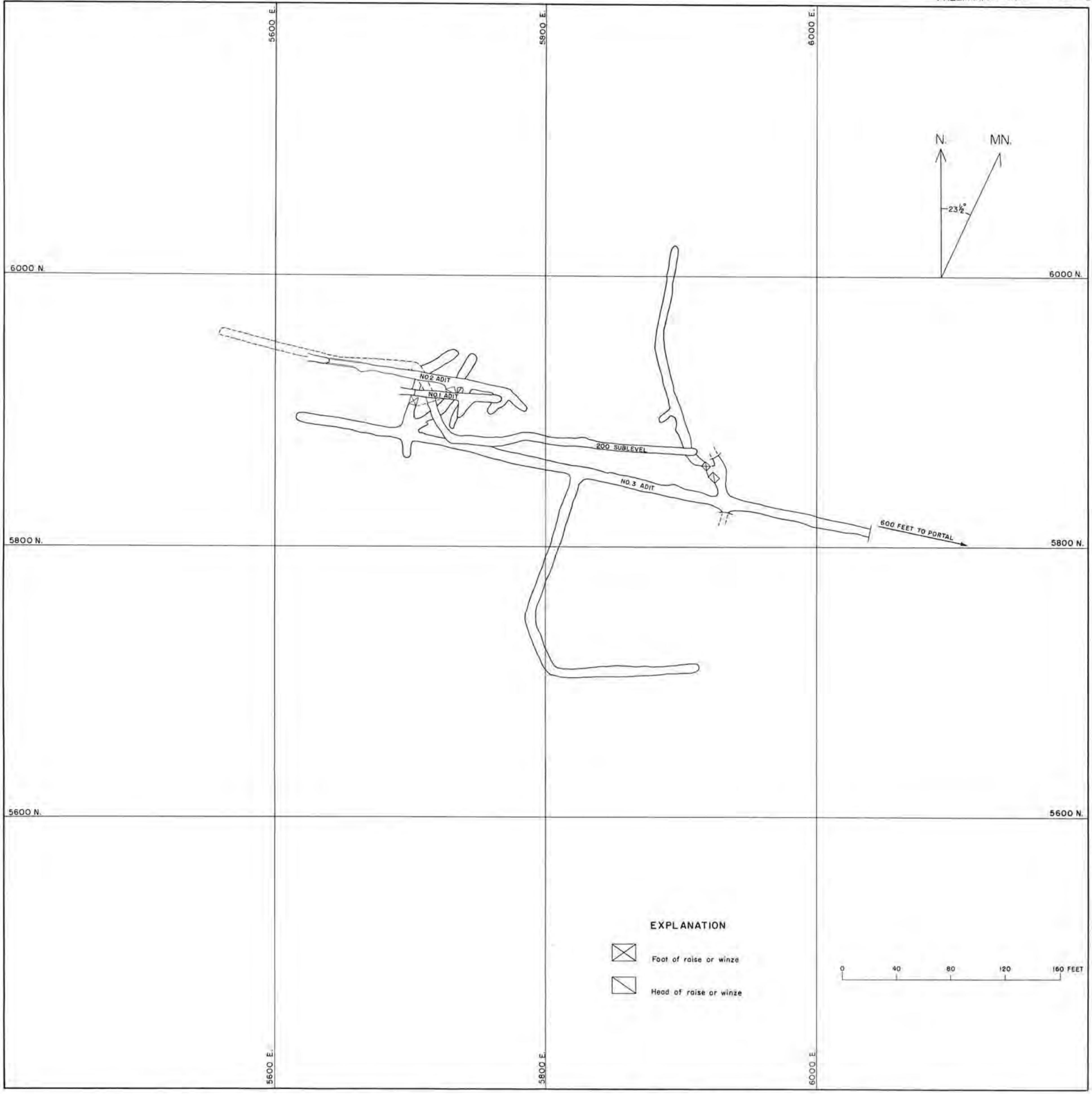




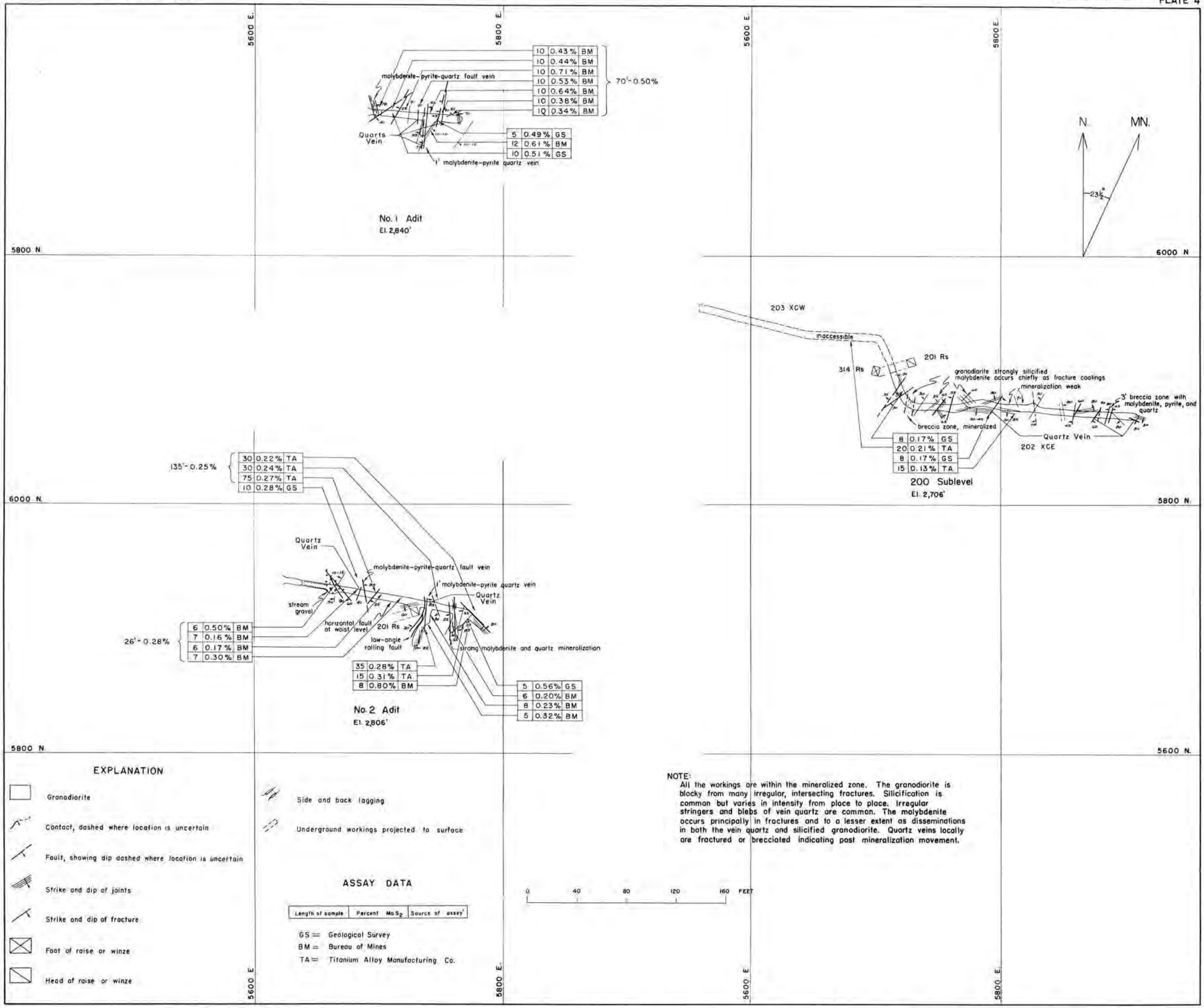
GEOLOGIC MAP OF MINERALIZED AREA, STARR MOLYBDENUM MINE, OKANOGAN COUNTY, WASHINGTON

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

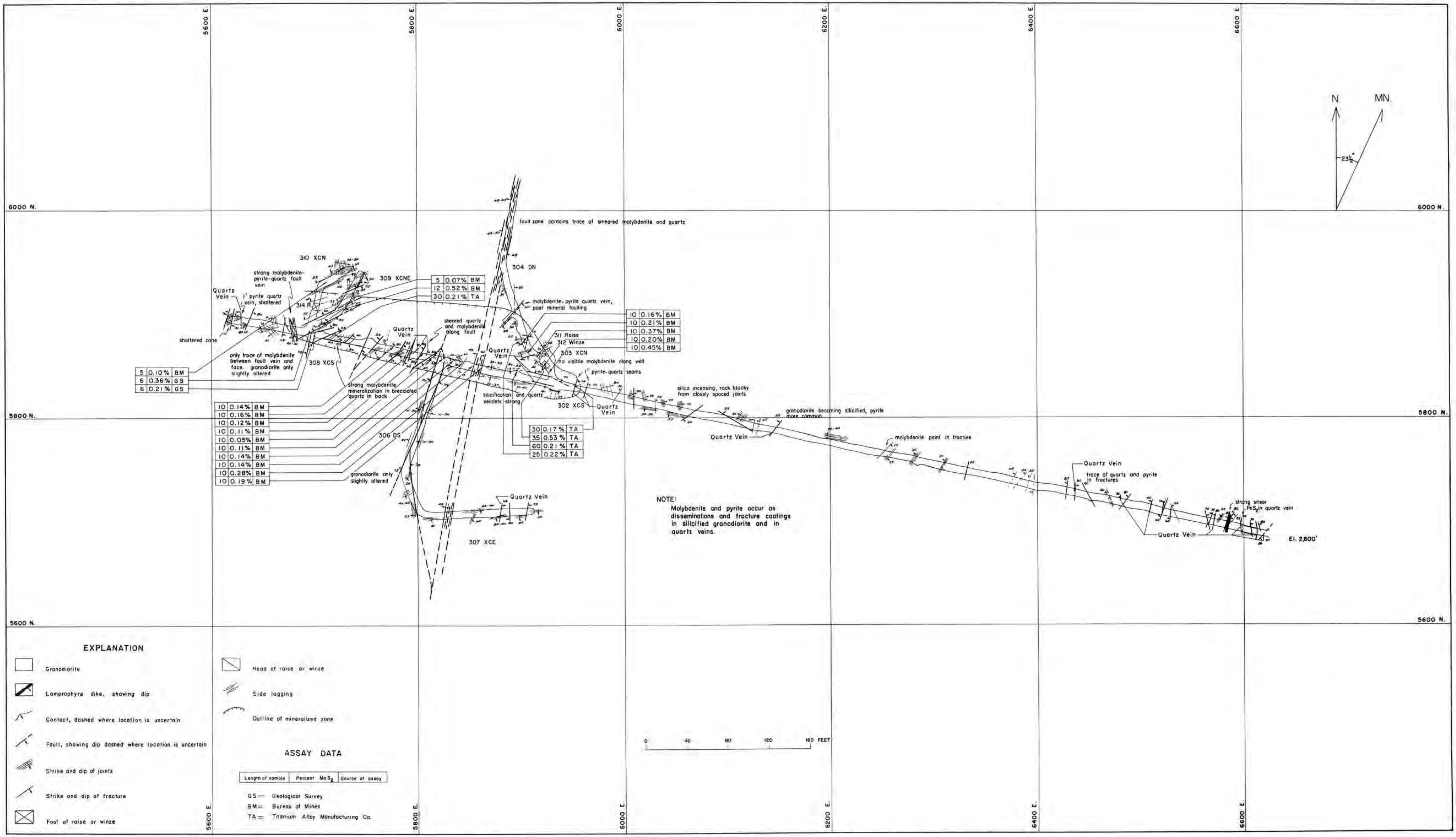
STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP PLATE 3



COMPOSITE LEVEL MAP, STARR MOLYBDENUM MINE, OKANOGAN COUNTY, WASHINGTON



GEOLOGIC MAP OF NO. 1 ADIT, NO. 2 ADIT, AND 200 SUBLEVEL, STARR MOLYBDENUM MINE, OKANOGAN COUNTY, WASHINGTON



5	0.07%	BM
12	0.52%	BM
30	0.21%	TA

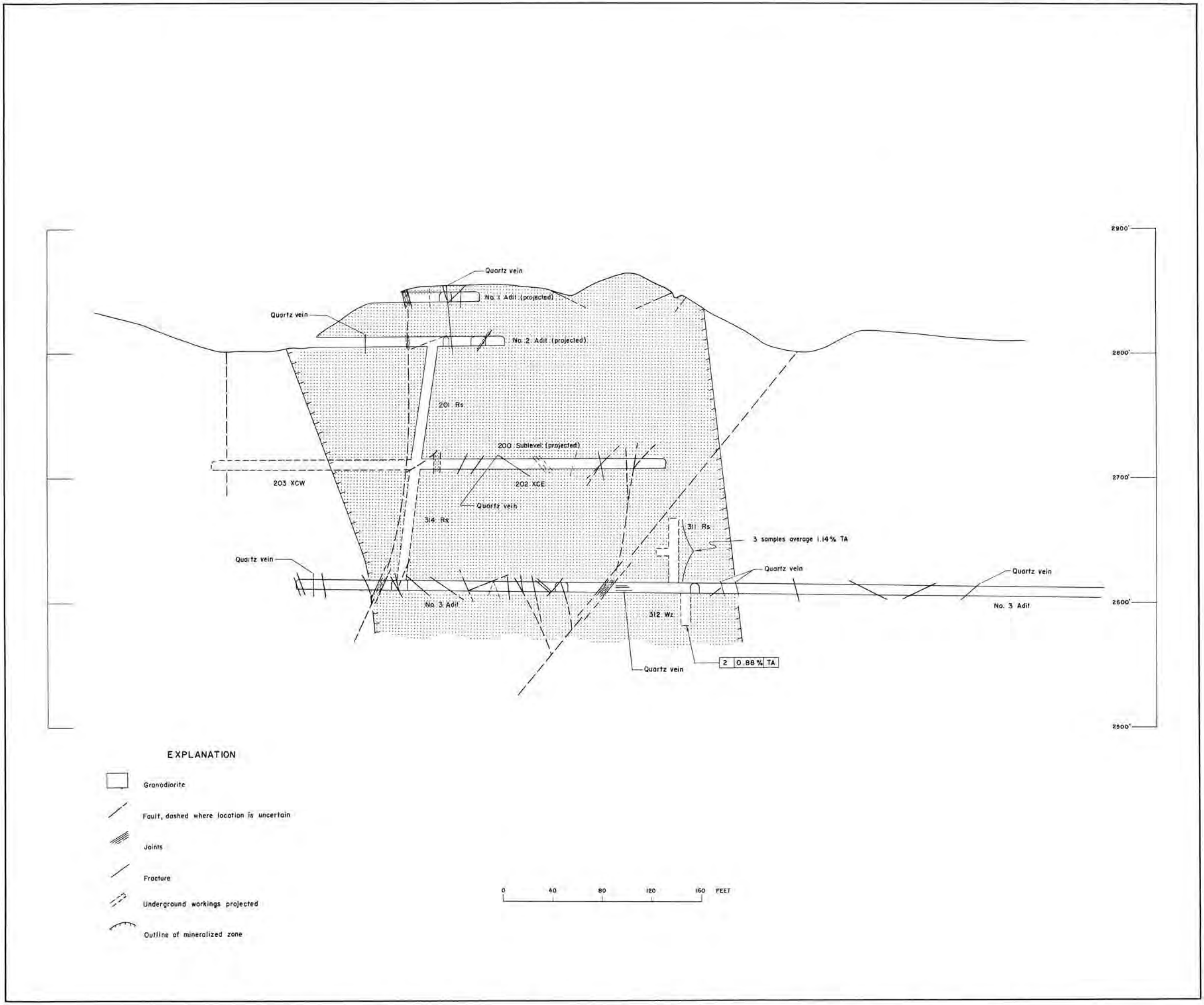
10	0.16%	BM
10	0.21%	BM
10	0.37%	BM
10	0.20%	BM
10	0.45%	BM

5	0.10%	BM
6	0.36%	GS
6	0.21%	GS

10	0.14%	BM
10	0.16%	BM
10	0.12%	BM
10	0.11%	BM
10	0.05%	BM
10	0.11%	BM
10	0.14%	BM
10	0.14%	BM
10	0.28%	BM
10	0.19%	BM

30	0.17%	TA
35	0.53%	TA
60	0.21%	TA
25	0.22%	TA

GEOLOGIC MAP OF NO. 3 ADIT, STARR MOLYBDENUM MINE, OKANOGAN COUNTY, WASHINGTON



SECTION THROUGH NO. 3 ADIT, STARR MOLYBDENUM MINE, OKANOGAN COUNTY, WASHINGTON