NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

Department of Geology

# The "Questa" Molybdenum Mine, Taos County, New Mexico

A thesis
by

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Submitted in partial fulfillment of
the requirements for the degree of
Master of Science

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ABSTRACT

The Questa Molybdenum Mine, Taos County, New Mexico, is unique in containing high-grade molybdenite ore in large fissure veins while most other production is from disseminated low-grade deposits. Operations began in 1916, and the mine has been in almost continuous production since then. Mining is by open and cut-and-fill stoping; concentration is by flotation. The ore contains 1 to 5 percent molybdenite. During the year ending June 30, 1951, production amounted to 83 tons of 90 percent molybdenite concentrates, worth $92,994.

The ore occurs in an albite-rich granite stock along its east-west striking, south-dipping contact with greenstone. The veins range from less than an inch to 7 feet in thickness and are largely quartz and molybdenite, with pyrite, fluorite, chalcopyrite, and biotite locally abundant, and galena, sphalerite, and rhodochrosite present in smaller amounts. The apparent order of deposition was: (1) quartz; (2) quartz, molybdenite, and biotite; (3) pyrite, chalcopyrite, galena, and sphalerite; (4) fluorite; (5) rhodochrosite; and (6) later small amounts of molybdenite. The deposit is hydrothermal and occured during the Tertiary, and soon after the intrusion of the granite.

Two sets of fractures, one parallel to the granite contact and the other a regional east-west striking, north-dipping set, control the location of the ore bodies. They opened up where their dips opposed each other and their strikes were parallel.

# INTRODUCTION

## Location

The Questa Molybdenum Mine (also known as the Moly Mine)[1] is located between 7500 and 9000 feet above sea level on the rugged western flank of the Sangre de Cristo Mountains in Taos County, New Mexico (see Fig. 1). The present surface plant is located along Red River Canyon seven miles upstream from the town of Questa, while adits to the older workings and the oldest mill are along Sulphur Gulch, an intermittent tributary of Red River.

## Accessibility

State Highway 38, a well-graded gravel road, passes the mine. It follows Red River Canyon and connects the mine with Questa seven miles to the west and the town of Red River six miles to the east. From Questa, highways lead to Taos, New Mexico (to the south) and Fort Garland (to the north). East of Red River, State Highway 38 crosses Red River Pass to Moreno Valley, and Eagle Nest, a distance of 19 miles. From Eagle Nest highways lead to Taos and Raton, New Mexico. All other roads are primitive and in many places ungraded and badly washed. Bus service to the mine is not available.

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[1] Although the name "Questa Molybdenum Mine" has been used in geologic literature, the name "Moly Mine" is more widely known.

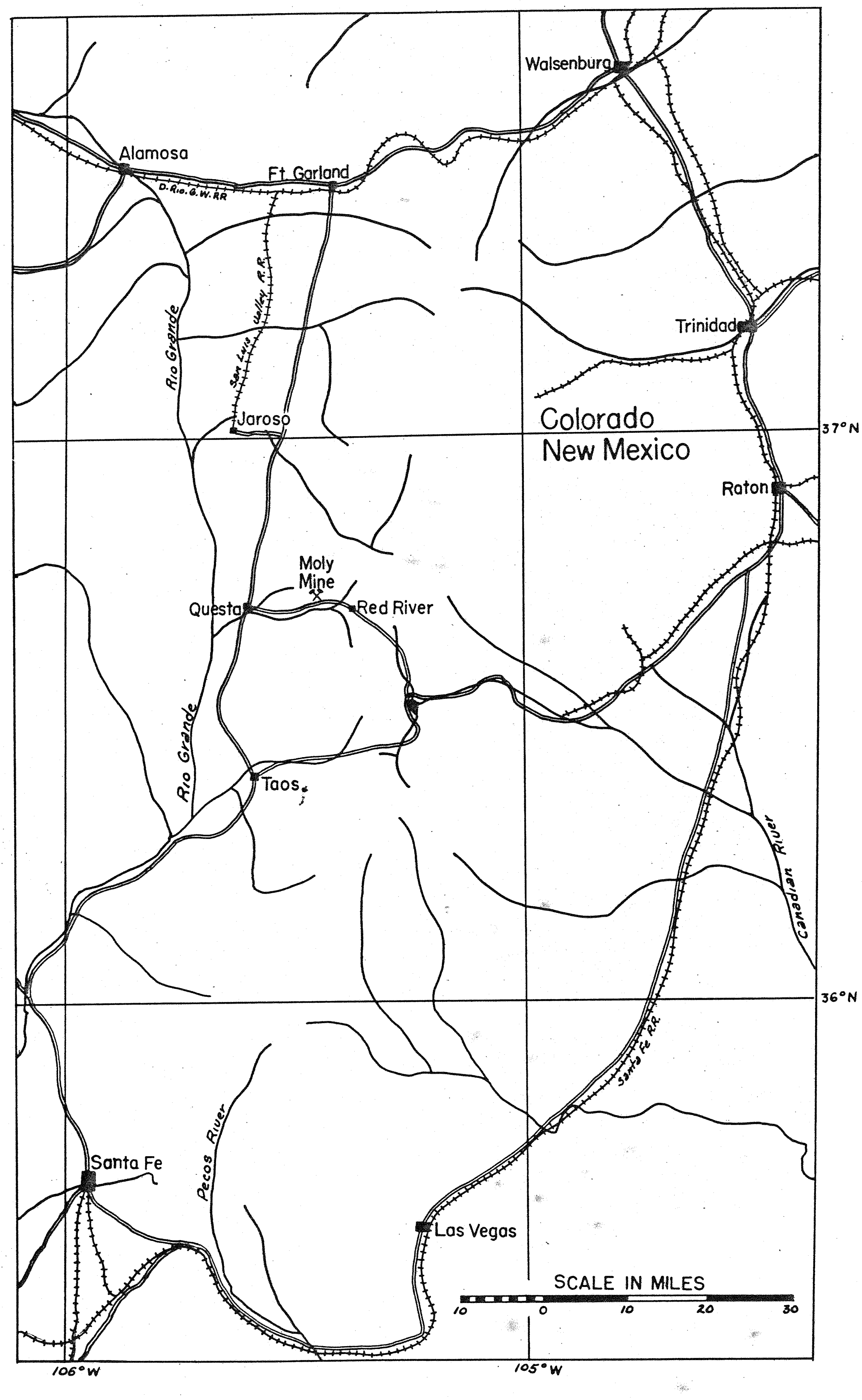



Figure 1. Location of the Questa Molybdenum Mine.

The nearest railroad is at Jarosa, Colorado, 25 miles northwest of Questa. Jarosa is the southern terminal of the San Luis Valley Southern Railroad which connects with the Denver, Rio Grande, and Western Railroad at Blanca, Colorado. Passenger service is not available but all heavy freight and molybdenite concentrates are trucked from the mine to the railroad at Jarosa.

## Topography

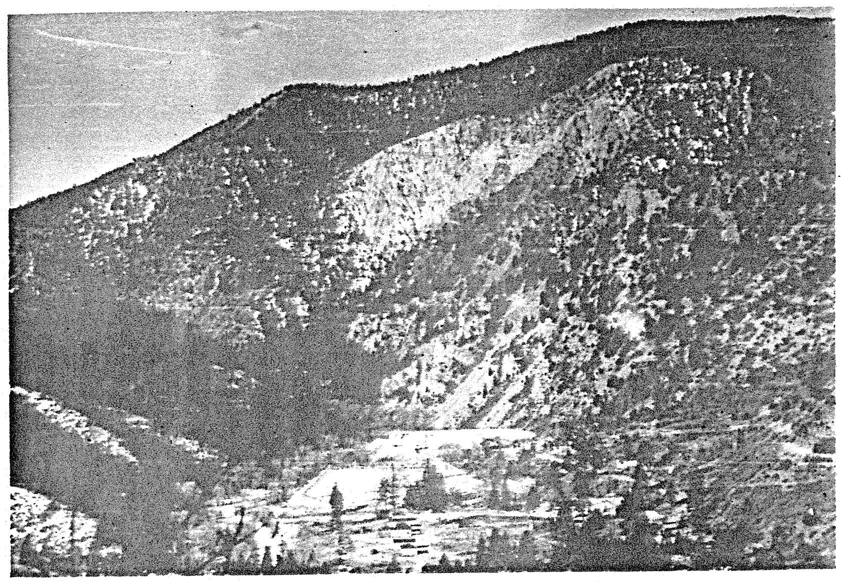
The Sangre de Cristo mountains in which the mine is located are part of the Southern Rocky Mountain physiographic province. The maximum relief is over 5000 feet. Wheeler Peak (elevation 13,155 feet), which lies 10 miles southeast of the mine, is the highest point in New Mexico. Red River ranges in altitude from 7800 feet at Questa to 9400 feet at the junction of the West and East Forks.

## Drainage

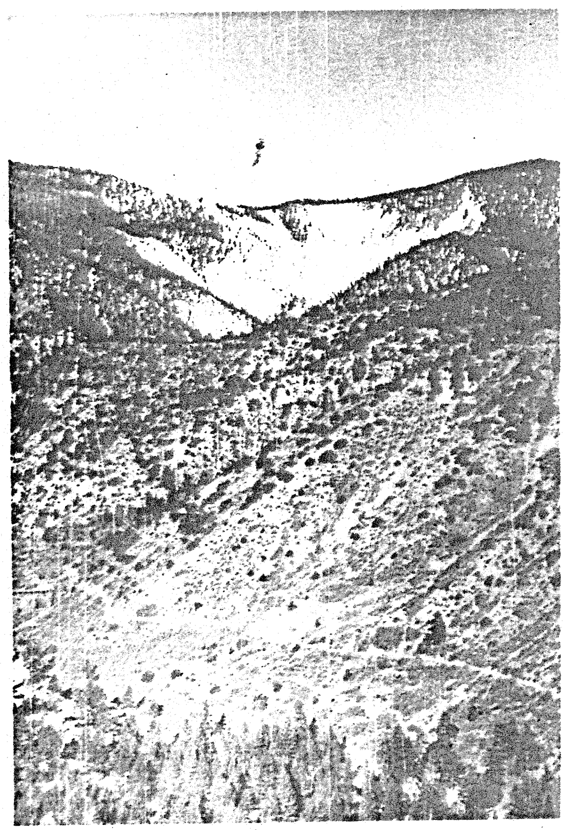
The surface over the mine is drained by Sulphur and Blind Gulches, intermittent tributaries of Red River. Red River flows westward into the Rio Grande four miles west of Questa.

## Water Supply

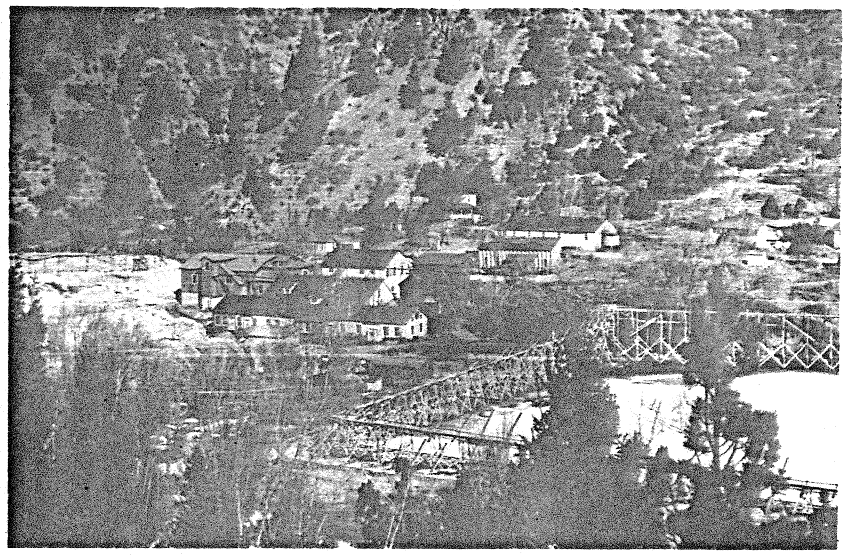
Water used in the mill for flotation and power is taken from Red River. This water is often too bitter for drinking



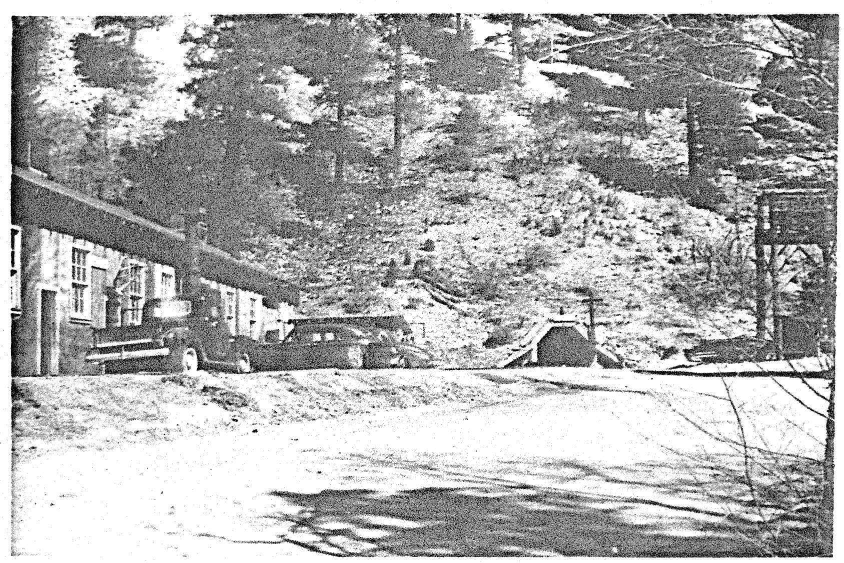
A. Moly Mine Camp in Red River Canyon



B. Altered Area at the Head of Sulphur Gulch



A. Moly Mine Mill and Camp



B. Compressor House and Portal of the Mile Long Adit purposes because of the iron salts dissolved in it (from the decomposition of pyrite disseminated through the rocks of the area), and drinking water for the company houses is obtained from a spring on the southern slope of Red River canyon opposite the mill.

Climate

The mine is subject to the type of climate characteristic of areas of high altitudes and great relief. During the summer the days are hot and the nights cool. In the fall the days remain hot, but the nights are cold. The winters are mild and the roads are seldom blocked with snow for more than a day, the heaviest snowfall being limited to the highest parts of the range. Occasionally the temperature remains below freezing long enough to reduce the flow in the flume and the mill must be shut down. Warmer weather comes in March bringing on dry windy weather with many dust storms. The mill sometimes is shut down during the driest part of this period. In May and June local rains occur, but the regular rainy season is from July through August. The torrential rains during this period cause flash floods in the side canyons.

## Purpose and Method of Investigation

This report was written as a thesis for the degree of Master of Science in Geology at the New Mexico Institute of Mining and Technology.

The writer first worked in the area during the summer of 1950 as an assistant to Phillip McKinlay who was mapping the geology of the Taos Range of the Sangre de Cristo Mountains for the New Mexico Bureau of Mines and Mineral Resources.

The field work was done in February, March, and April 1951. The geology of all the accessible working was mapped on a scale of 1 inch equals 20 feet. The surface geology was mapped on a scale of 1 inch equals 100 feet.

Most of the laboratory work, drafting, and writing was done at Socorro during the summer of 1951, although a small amount was completed in the field.

## Previous Work

Vanderwilt[1] examined the mine in 1934 and the surface area west of the mine in 1945. These reports are good but integration with the regional geologic picture is lacking. Development of lower levels and the main adit has also added valuable information from areas which Vanderwilt has as yet

1 Vanderwilt, J.W., "Geology of the Questa Molybdenite Deposit", Colo. Sci. Soc. Proc. vol. 13, no. 11, 1938; and "Geology of the Area West of Sulphur Gulch and Its Relation to the Molybdenite Deposits", unpublished report to the Molybdenum Corporation of America, Sept. 20, 1940.

been unable to examine. Carman,[1] general manager at the mine, has written reports on the milling and mining methods but since the reports were written mining methods have changed and the mill has be rebuilt.

Acknowledgements

The writer is indebted to J. B. Carman, general manager; Al Greslin, assistant manager and mill foreman; Bill O'Toole, mine clerk; and Ben Horner, mine foreman, who went out of their way to help.

I also wish to express my thanks to Dr. J. E. Allen and Dr. C. T. Smith of the Geology Department for critically reading the manuscript, and to Phillip McKinlay who introduced the regional geology to me.

A special vote of thanks goes to Dr. Eugene Callaghan, Director of the New Mexico Bureau of Mines and Mineral Resources, for the use of drafting equipment and laboratory facilities.

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[1] Carman, J.B., "Milling Methods at the Questa Concentrator of the Molybdenum Corporation of America", U.S. Bur. of Mines, I.C. 6551, Jan. 1932; and "Mining Methods of the Molybdenum Corporation of America at Questa, New Mexico", U.S. Bur. of Mines, I.C. 6514, Sept. 1931.

## HISTORY

The presence of the altered areas and gossan zones was known for many years, but prior to 1916, the yellow molybdite gossan at the outcrops of the veins was thought to be sulphur, giving the name Sulphur Gulch to the valley in which the outcrops occur. The black molybdenite was mistaken for graphite, and the mineral had actually been mixed with grease and used by nearby farmers as a lubricant.

In 1916 or 1917, Jimmy Fay, a miner having claims along Sulphur Gulch, sent a specimen of ore containing molybdenite to San Francisco to be assayed for gold and silver. The beginning of World War I had greatly increased the demand for molybdenum and assayers were thus becoming aware of the value of the mineral molybdenite. When the assayer returned his report, he mentioned the presence of molybdenite and its value.

Some claims were located during the war and the Western Molybdenum Company of La Jara, Colorado was organized to develop the claims. In November 1918, the R and S (Rapp and Savery) Molybdenum Company of Denver was formed and took over seven claims, the Phyllis Group, of the Western Molybdenum Company. This new company filed additional claims, increasing their holdings to 300 acres. Development work was

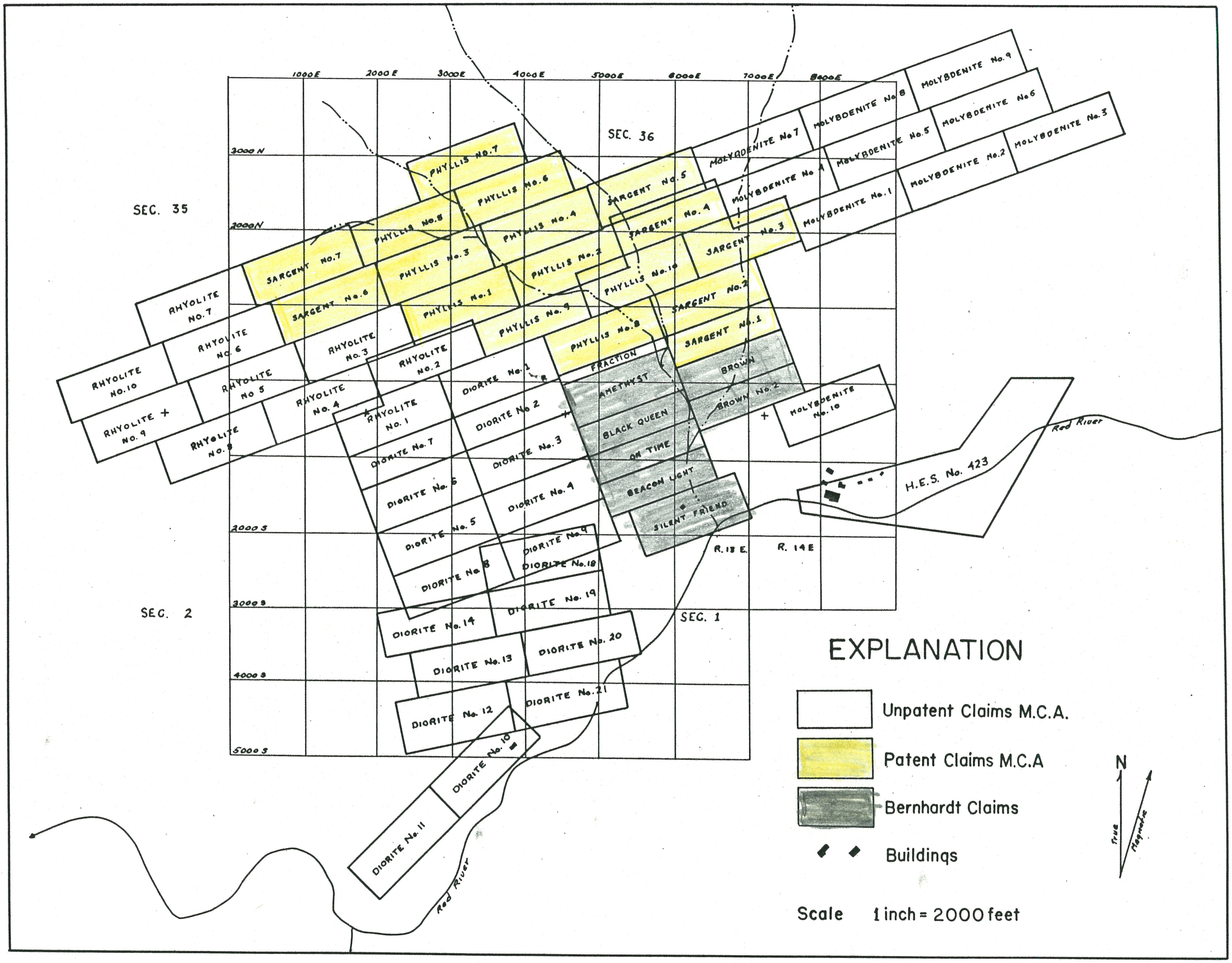



Figure 2 Claims of the Molybdenum Corporation of America at Questa, New Mexico.

done throughout the winter; production began in the spring of 1919. The ore was treated at a converted gold mill on Red River about five miles above the mine.

The Molybdenum Corporation of America was incorporated in 1920 and in the same year acquired the property of the R and S Molybdenum Corporation. Mining was discontinued during the depression of 1921. However, development work was continued, and in 1923 a 40-ton flotation mill was built on the present mill site. In 1929, a new mill was built on the same site. Because of the inaccessible location of the workings, burros were used to haul the ore from the portals to the bottom of Sulphur Gulch.

With increased depth of the workings, hoisting and tramming costs increased rapidly. In 1945, to lower the handling costs, the Moly Tunnel (an adit a mile in length) was driven north from Red River to the workings. This adit connected with the lowest mine level, which was at the same elevation. At present the workings have reached a point 240 feet below the adit. The mill was rebuilt at about the same time.

Other companies had ~~have~~ attempted to mine molybdenite in the area but were unsuccessful because of a lack of ore. In 1924, the Hercules Molybdenum Corporation built a camp at

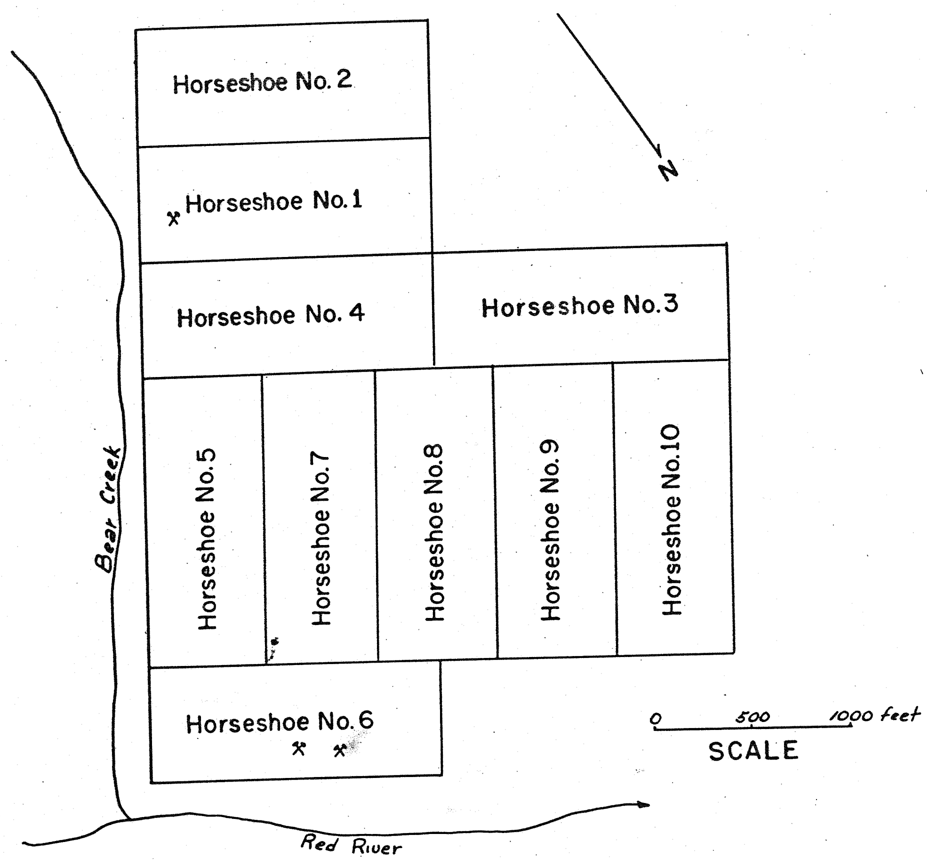



Figure 3. Horseshoe (Bear Creek) Claims.

the head of Sulphur Gulch and did some development work. Apparently little ore was found because the company abandoned the camp the following year.

More recently several adits were driven along Goat Hill Gulch to the west of the mine. These prospects ~~are~~ were known as the BJB Prospects. Some ore was produced and milled at the Moly Mine mill but the prospects are no longer being worked.

*Dan Cisneros and Juan Aragon of Questa are working a group of claims, known as the Horseshoe Claims (see Fig. 3), located along the south side of Red River Canyon 4 miles west of the Moly Mine.

Mr. Leroy Bernhardt, a prospector who has been in the area since the discovery of molybdenite, has a group of claims along the lower part of Sulphur Gulch (see Fig. 2). When he opened the prospects on these claims a good vein of silver ore was found, but proved to be limited in extent. Only traces of molybdenite were found.

# GENERAL GEOLOGY

## Stratigraphy

The core of the range is made up of Precambrian rocks which have been intruded by granodiorite and granite stocks and dikes, and covered by quartz latite, andesite, and rhyolite flows, breccias, and tuff. Only a small belt of sediments is present in the area around the mine.

### Precambrian

Precambrian rocks form the core of the Sangre de Cristo Range. None of the Precambrian rocks were studied in any detail since there is no apparent relation or association of these rocks and molybdenite mineralization. For mapping purposes, gneissic granite, quartzite, and undifferentiated metamorphic rocks have been distinguished and given names.

Columbine Granite Gneiss   Granite gneiss is exposed over large areas of the Sangre de Cristo Range and is found south of the Sulphur Gulch albite-rich granite stock and in the southern half of the Moly Tunnel. The granite is composed of quartz, orthoclase, biotite, and pyroxene. The pyroxene is at the center of clusters of biotite. Biotite folia forming the gneissic structure strike east-west and dip vertically.

Cabresto Quartzite   Quartzite is exposed over large areas of the Sangre de Cristo Range and is found on the divide north of Blind Gulch. The quartzite is massive and coarsely crystalline with lenses of garnet schist exposed near the top of the unit. The thickness was not measured because of the poor exposures and complex faulting.

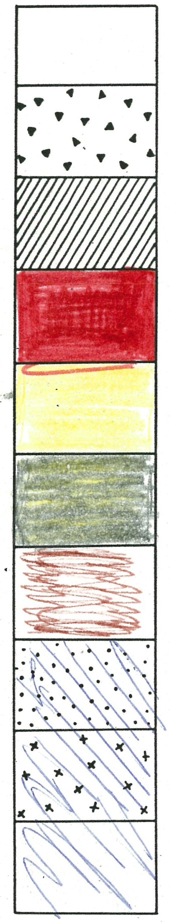
Gold Hill Metamorphics Other metamorphic rocks including chlorite schist, amphibolite gneiss, amphibolite, and metagabbro are exposed southwest of the Sulphur Gulch stock and over large areas south of Red River. Amphibolite is exposed in the Moly Tunnel. Chlorite schist probably is present in the mine as part of the greenstone complex.

Pennsylvanian (?) Sediments

A belt of sedimentary rocks extends from Red River across the divide to Cabresto Canyon and is cut by the Sulphur Gulch albite-rich granite stock. South of the stock the belt consists of conglomerate overlain by shale. North of the stock, limestone is found above the conglomerate and shale. The age of these sediments is uncertain. Vanderwilt[1] is reported to have found poorly preserved plant remains in the shale south of the stock. The lithology suggests that these sediments may be correlated with the Magdalena formation of Pennsylvanian age, although the limited exposures make

1 Personal communication - J.B. Carman, general manager.

# KEY



Quaternary

Valley Fill

Tertiary

Altered Areas

Greenstone Complex

Albite Granite

Rhyolite Tuff, Flows, Breccia

Andesite Tuff, Flows, Breccia

Paleozoic

Conglomerate, Shale, Limestone

Precambrian

Quartzite

Gneissic Granite

Metamorphics

② ④ Prospects
- 1 - Horseshoe
- 2 - BJB
- 3 - Hercules
- 4 - Bernhardt

ZT W Moly Mine Portals
- TS – Mile Long Adit
- Z — Z Level
- 3T – No 3 Level
- BG – Blind Gulch Tunnel
- GH – Glory Hole Workings
- W — W Level

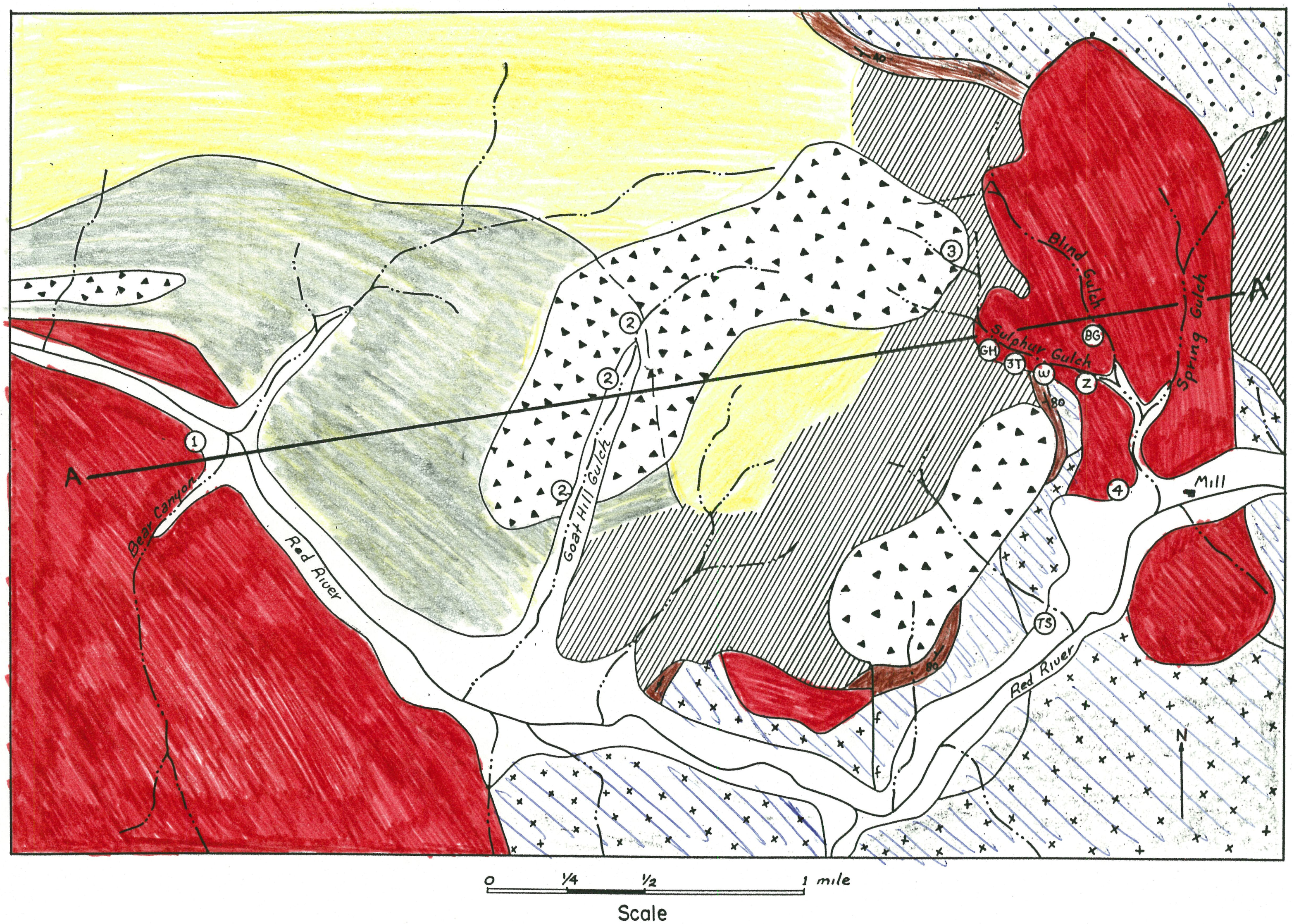



Figure 4. Geologic Map of the Questa Molybdenum Mine Area.

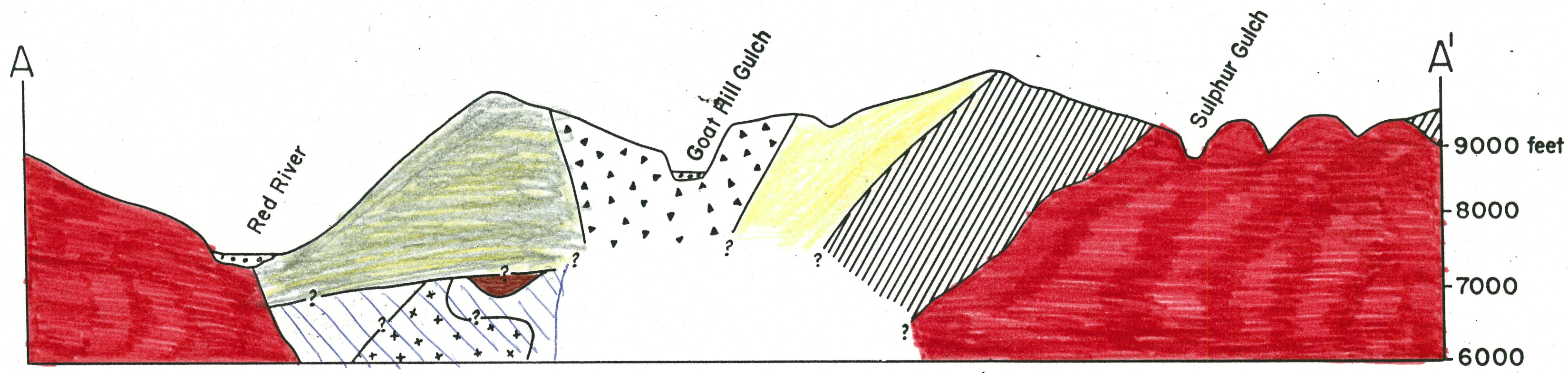



Figure 5. Cross Section of the Questa Molybdenum Mine Area. (See Fig. 4 for the location of the cross section and the key, 2 pages back, for an explanation of the rock types.)

any correlation uncertain.

The conglomerate consists of well-rounded 1 to 6 inch pebbles of quartzite, chlorite schist, granite gneiss, and quartz in a matrix of recrystallized feldspathic grit. Chlorite is abundant in the matrix and most of the pebbles. In places boulders 3 feet across were seen. Conglomerate is reported in the No. 3, W, and Z levels of the mine.[1] At the outcrop along Red River 3 miles west of the mine the conglomerate has a thickness of 8 feet.

The shale is red and arenaceous at the outcrop along Red River. At all the other outcrops the shale has been metamorphosed to green to black, dense-grained hornfels. The shale has not been noted in the mine, probably because it resembles the other types of rocks making up the greenstone complex. At the outcrop along Red River the shale is 12 feet thick.

The light gray limestone is poorly exposed at all its outcrops. It is approximately 2 feet thick. The outcrops were checked for replacement deposits but no mineralization was found. The limestone is overlain by volcanic flows. Limestone has been reported in the mine at several spots.[1]

Tertiary Rocks

Goat Hill Gulch Rhyolite   Rhyolite tuffs, flows, and

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[1] Levels now caved. Shown on the company maps and confirmed by J.B. Carman, general manager, and Ben Horner, mine foreman.

breccias cover large areas west of the Sulphur Gulch stock and north of Red River. The most common variations are:

1. A porphyry showing quartz phenocrysts 1/8 inch across in a porcelain-like groundmass.

2. A porphyry with quartz and feldspar phenocrysts 1/8 inch across in a dense groundmass.

3. A fine-grained rock with a uniform sugary texture.

4. A gray to dark-gray rock showing flow lines with dark bands. Flow bands are 1/32 to 1/4 inch thick. The flow lines are well developed in Goat Hill Gulch, and trend N50°-70°W with nearly vertical dips. In Capulin Gulch 4 miles east of the mill, the flow lines trend N30°-40°W and dip vertically.

5. A flow breccia composed of angular pieces of porphyry (types 1 and 2 above) in the rhyolite.

All the varieties contain orthoclase, quartz, and some albite. Pyrite is usually present and hydrothermal alteration might have changed some of the original constituents of the rock. The rhyolite is similar to the albite-rich granite in composition but is definitely older since the Sulphur Gulch stock is intruded into the rhyolite. The stratigraphic relation of the different types of rhyolite to each other and to the other volcanics is obscured by alteration, faulting, and weathering.

<u>Goat Hill Gulch Quartz Latite and Andesite</u> Quartz latite and andesite cover large areas to the west and east of the mine. Near the stock they have been altered to greenstone. The quartz latite is porphyritic and shows

quartz and lath-shaped feldspar phenocrysts. The andesite occurs as a porphyry and a phanerite. Because of poor exposures the stratigraphic relationship between rhyolite and the andesite and quartz latite was not determined. The quartz latite and andesite are either sill or flows (or both) and are cut by the albite-rich granite, as well as later andesite and quartz latite dikes.

Albite-Rich Granite  Three areas of albite-rich granite are found along Red River. The largest area, a stock, lies near the mouth of Red River Canyon 5 miles west of the mill. This stock does not extend far north of Red River, and south

TABLE 1
COMPOSITION OF THE ALBITE GRANITE

| | quartz | orthoclase | albite | biotite | other minerals |
|---|---|---|---|---|---|
| 1. | 50% | 25% | 20% | 5% | sphene, magnetite |
| 2. | 45 | 40 | 15 | trace | magnetite |
| 3. | 43 | 35 | 20 | 1 | sphene |
| 4. | 32 | 20 | 47 | none | magnetite |

1 - Dike; opposite mouth of Columbine Canyon; porphyritic (phenocrysts of quartz and orthoclase)
2 - Stock; mouth of Red River Canyon; phenocrysts of quartz and orthoclase.
3 - Stock; Sulphur Gulch; north of the Moly Mine.
4 - Stock; Sulphur Gulch; description of Larsen and Ross, "The R & S Molybdenum Mine", Econ. Geol., vol. 15, no. 7, p. 569, 1920; this rock is called alaskite porphyry.

of the river it rises abruptly to altitudes over 2,500 feet above the canyon floor, forming Flag Mountain. A small area of granite occurs north of Red River opposite the mouth of Columbine Canyon. The stock through which Sulphur Gulch cuts

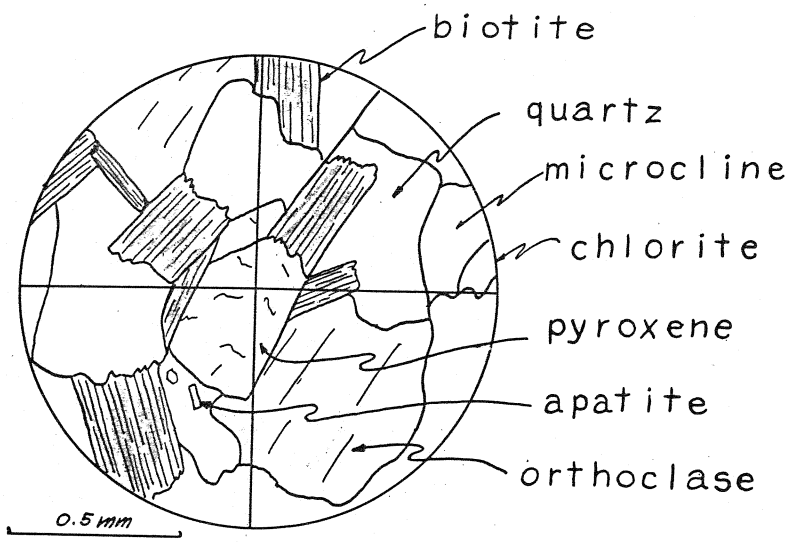



Figure 6. Thin Section of Gneissic Granite.

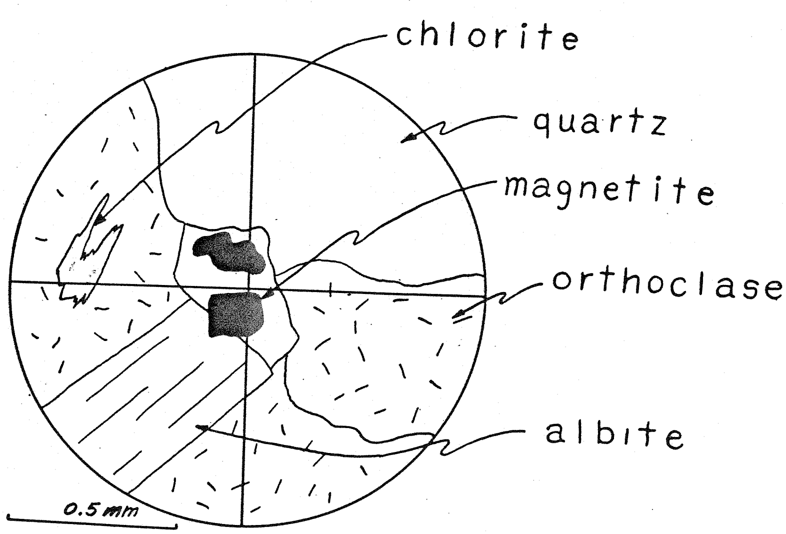



Figure 7. Thin Section of Albite Granite.

(known as the Sulphur Gulch stock), in which the Moly Mine is located, this the third area of granite. Dikes of granite are common throughout the area and usually have an east-west trend and a steep dip to the north. In the mine dikes of all sizes are found in the greenstone near the granite stock. In places the greenstone has been highly brecciated and intruded by granite, resulting in numerous greenstone xenoliths,

The granite is composed of quartz, orthoclase, albite, and biotite, with small amounts of sphene, magnetite, apatite, and zircon. (See Fig. 7 and Table 1) This rock was termed a sodic granite in previous reports because of the large percentage of albite. The amount of biotite varies from 10% to completely absent. When the biotite is completely absent it has been call soda-potash alaskite porphyry. Some sericite is present as an alteration product from biotite; chlorite is an alteration product from biotite. Fresh rock is pink in color accounting for the term "redrock" which the miners use for the granite. Where porphyritic, the rock has phenocrysts of orthoclase or quartz (or both); grain size varies from 1/4 inch to 1/16 inch. The granite is fine-grained at the contact and coarser away from it. Dikes in the surrounding rocks range from aphanitic to phaneritic in texture and are commonly porphyritic. Granulation is widespread and can be seen in most of the thin sections.

Post-Granite Dikes  Random dikes of andesite, dacite, and diabase are common. One late dike of this group exposed in the mine ranges from andesite to dacite in composition. One-tenth to a half inch lath-shaped phenocrysts of feldspar (andesine) are scattered through the dike; rounded one-tenth to three-tenths inch phenocrysts of quartz are present in places. The dike exposed in the mine cuts vein structures, granite, and greenstone.

Quaternary

Valley fill is the only Quaternary deposit in the area around the mine. Quaternary basalt and gravels of the Santa Fe formation cover the plain west of the mountains.

## Alteration

Greenstone Complex  Along the southwest and east border of the Sulphur Gulch albite-rich granite stock the rocks have been altered to form the "greenstone complex". Because of the intensive alteration it is not possible to distinguish the rock types which make up the complex, and it is therefore a matter of mapping convenience to apply the term "greenstone complex" to this unit of obviously diverse origins. On the surface good outcrops are limited but underground exposures are excellent.

The "greenstone complex" is a series of light to dark gray rocks with a greenish cast due to the presence of chlorite and epidote. There is considerable variation in composition, however certain features are found in all the samples. Most of the rock has been altered to chlorite which makes up from 40% to 70% of the composition. Feldspar has been altered to epidote. Most of the samples are extremely fine-grained and even high magnification does not yield much information.

The "greenstone complex" was probably derived from the alteration (chloritization and epidotization) of the enclosing rocks by solutions and gases which emanated from the albite-rich granite during or shortly following its intrusion. The amount of alteration decreases away from the granite contact. Precambrian schist, Pennsylvanian (?) shale, and Tertiary andesite and quartz latite the rocks which have been altered to form the complex. As these units are traced toward the contact they grade into rock which has been so intensely altered that no traces of the original types remain. Other rock units may have been altered to form part of the "complex" but if so they have left no clue to their existence. Where Precambrian granite gneiss and quartzite, Pennsylvanian (?) conglomerate, and Tertiary rhyolite are in contact with the granite only minor amounts of alteration has occurred.

Altered Areas  Areas of altered rock are found along the north side of Red River Canyon from the mouth at Questa to the town of Red River, then northeast along Bitter Creek. Three large areas are found in the vicinity of the mine: (1) at the head of Goat Hill Gulch, (2) at the head of Sulphur Gulch, and (3) an area south of the Sulphur Gulch stock and north of Red River Canyon. These altered areas are conspicious since they have no cover of trees or other vegetation and are bright yellow. The surfaces are badly eroded forming steep "badland" type slopes. Material from these areas form deep alluvial fans in Red River Canyon and the water draining from them is bitter with dissolved iron salts. Sulphur Gulch and Bitter Creek are names which reflect their location in the altered areas. The boundaries of the areas are irregular and gradational.

Tertiary volcanics comprise the rocks which have been altered. Alteration products are kaolinite, sericite, quartz, and pyrite. Pyrite is the most common and widespread, occuring as grains disseminated through the rock. The feldspar has been altered to sericite which in turn has weathered to kaolinite. Oxidation of pyrite and other minerals has formed alum, limonite, and gypsum.

Paint thin seams of molybdenite cut all other mineralization in the mine indicating that the alteration is younger than the ore mineralization as well as the granite. Disseminated pyrite in the granite at some distance from the ore mineralization also suggests a later age.

The altered areas represent hydrothermal alteration, further changed by surface weathering and erosion. Irregular veins of pyrite, quartz, fluorite, molybdenite, and some chalcopyrite and galena are scattered through the altered areas. All these minerals except molybdenite are common in low temperature deposits and molybdenite is being deposited by hot springs in the Valley of Ten Thousand Smokes, Alaska, where thermal springs are regarded as the late phase of volcanic activity. The altered rhyolite exposed along Yellowstone Canyon, Wyoming, is similar to the Red River areas, and also suggests that the altered areas around the mine were formed by "hot spring" alteration as a late phase of volcanic activity.

## Regional Structure

The regional structure of the Sangre de Cristo Mountains has not been studied in detail. The range is an uplifted fault block with sedimentary rocks tilted up along its western flanks.

The elliptical intrusion of albite-rich granite in Sulphur Gulch has a longer north-south axis, while the stock at the mouth of Red River has its longest axis northwest-southeast. An east-west striking north-dipping fracture system is found around the mine.

## Geologic History

During Precambrian time sediments were deposited over the area which is the Sangre de Cristo Range. These sediments were intruded by granite; all were metamorphosed and later eroded. A record of what happened during most of the Paleozoic is missing but during the Pennslyvanian period sediments were deposited in a sea which covered the major part of the Sangre de Cristo Mountains. These sediments included conglomerate, shale, and limestone. Nothing is known about the Mesozoic era.

During the Laramide Revolution the region that is now the Sangre de Cristo Range was uplifted as a fault block and eroded. Volcanic activity filled the valleys with flows, tuffs, and breccias. A batholith of albite-rich granite intruded the older rocks; solutions and gases emanating from the granite altered surrounding rocks to greenstone. As the granite cooled, fractures formed along the contact and solutions from the deeper part of the batholith, which was still liquid, deposited molybdenite, quartz, and other minerals in the fractures formed by the cooling. During the last stages of volcanic activity, weaker solutions of hot spring intensity caused widespread alteration of the volcanic rocks and deposition of quartz, pyrite, and molybdenite.

Glaciation during the Pleistocene covered the higher parts of the range and carved out U-shaped valleys. This glaciation extended down Columbine Canyon to within a mile of Red River but did not reach any closer to the mine. Erosion formed alluvial fans on the plain to the west and numerous volcanoes poured out lava. During recent times the mountains have been eroded to their present form and material from the altered areas have formed fans along Red River. Faulting occurred but can not be dated.

# ECONOMIC GEOLOGY

## Mineralogy

### Ore Minerals

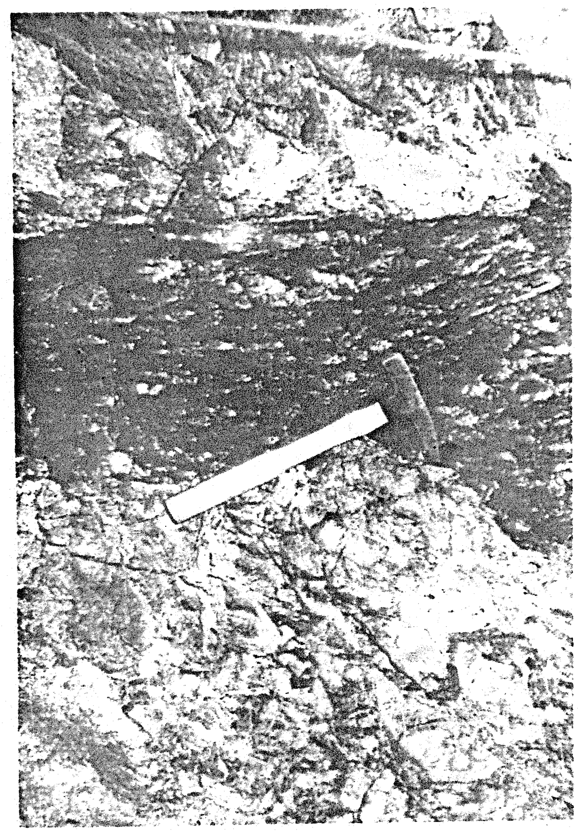
Molybdenite    Molybdenite is the only ore mineral. It is found in distinct veins and disseminated through the wall rock. Quartz, pyrite, fluorite, chalcopyrite, biotite, and rhodochrosite (in that order of abundance) are common associated minerals. The molybdenite is fine-grained, mud-like, soft, and has a black luster resembling graphite. It occurs intimately associated with quartz, pyrite, and biotite. Masses of almost pure molybdenite weighing several hundred pounds are occasionally found but break up and crumble so easily that large specimens rarely remain intact.

### Gangue Minerals

Quartz    Quartz is the most abundant gangue mineral. It occurs with the molybdenite and in the albite-rich granite as small veins which contain no other minerals. Veined quartz with stringers of molybdenite often produce a banded structure (see Plate IV). The quartz ranges in color from gray through white.

Pyrite    Pyrite is widely distributed in the area of molybdenite-quartz mineralization. It occurs disseminated through the granite and greenstone complex, in veins without

A. Pinch in a Quartz-Molybdenite Vein



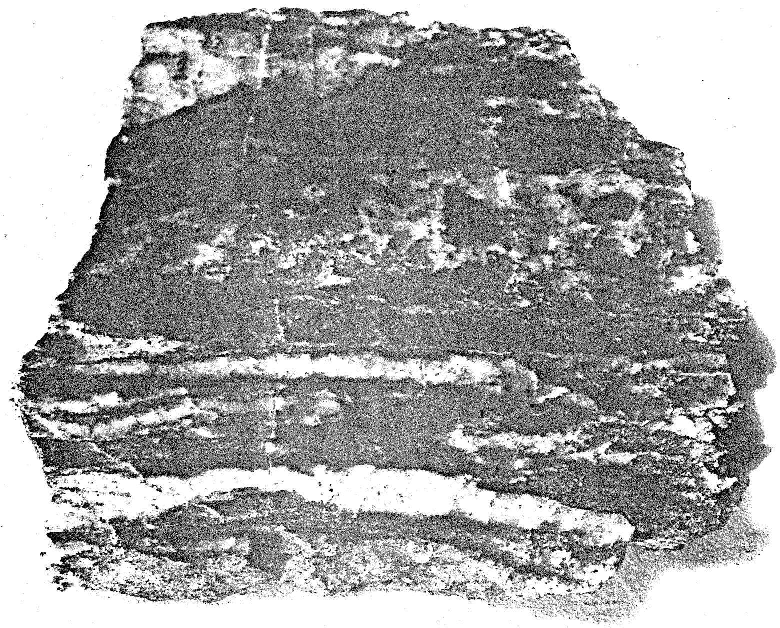
B. Typical Quartz-Molybdenite Vein

other minerals, and associated with the molybdenite and quartz. When the pyrite is present with the molybdenite it occurs in streaks or bunches, and if galena, sphalerite, or chalcopyrite are present they are associated with the pyrite. Cubes of pyrite are rare although a few up to an inch cubes were seen by the writer.

Fluorite Fluorite is very common and widely distributed. It is found in the veins with molybdenite and quartz and as angular brecciated pieces in rhodochrosite-calcite veins, as well as alone in veins up to 15 inches wide. Often veins containing mainly molybdenite and quartz will change in a short distance to veins containing only fluorite. It is common in the ore shoots, but is more abundant in the marginal areas of the molybdenite concentration. Its color varies from purple, green, and red, to white. No relation of color to association with other minerals could be found.

Chalcopyrite Chalcopyrite is present in fairly large amounts with the pyrite. It also occurs in small pockets with galena and sphalerite. Underground it is hard to distinguish chalcopyrite from pyrite.

Biotite Biotite is associated with the molybdenite and quartz and is widely distributed. Its presence is considered by the miners as a favorable sign for finding



A. Polished Section of a Banded Quartz-Molybdenite Vein

B. Polished Section of Wall Rock

ore grade molybdenite because it is conspicuous in the richer ore shoots. It is also found in quartz veins unaccompanied by other minerals. The biotite is usually in coarse flakes, soft and crumbly, with a dull brown luster. Under the microscope some of the biotite shows alteration to chlorite.

Orthoclase  Orthoclase forms most of the white-gouge material. It occurs in the molybdenite-quartz veins as well as along in veins. Some quartz is found in the white-gouge and sericite is present, however, thermal analysis indicates that there are little or no clay minerals present. Apparently the orthoclase is not formed by pulverization of the granite since the gouge is found in the greenstone and occurs in the granite without associated quartz or with very small amounts.

Rhodochrosite  Rhodochrosite occurs alone, with brecciated fluorite, with calcite, and in the center of molybdenite-quartz veins. It is fine-grained and pink in color until exposed to the air when it becomes iron-stained. The distribution is spotty, however, no pattern of occurrence was noted. The miners call the rhodochrosite "candy".

Chlorite  Large amounts of chlorite are present in the altered rocks making up the "greenstone complex". It is also found in the molybdenite-quartz veins and as seams in the granite which are known as "mud" by the miners.

<u>Calcite</u> Calcite occurs in the center of the molybdenite-quartz veins with rhodochrosite. It is more commonly found along fractures in the greenstone. It is more characteristic of the margins of the ore shoots than in the ore itself.

<u>Clay Minerals</u> Some of the feldspar in the granite has been altered to a clay mineral, probably montmorillonite (in index oils the mineral shows a mean index of about 1.53 with moderate birefringence; the thermal analysis curve is characteristic of montmorillonite). This alteration is conspicuous underground since the mineral swells after exposure to the air; giving the rock a psuedo-porphyritic appearance.

<u>Limonite</u> Limonite is common at the outcrops of the veins. In the mine it has formed by recent oxidation of the pyrite.

<u>Molybdite</u> Molybdite is found at the outcrop of the molybdenite-quartz veins; the molybdenite oxidizing to molybdite. This oxidation zone extends only a few feet below the surface. Some is also present in the older workings where the molybdenite has had time to oxidize. The molybdite is canary yellow and very conspicuous in places.

<u>Graphite</u> Graphite apparently is intimately associated with the molybdenite. When the mill first began operation,

concentrates which appeared to be over 80% molybdenite were found to contain only 40%. Tests showed that the concentrates contained large amounts of graphite, and new mill reagents were used to remove the graphite. Graphite apparently never occurs except with the molybdenite.

Galena Galena occurs in small amounts in pockets with chalcopyrite and sphalerite.

Sphalerite Sphalerite is found in small pockets with chalcopyrite and galena.

Malachite Malachite is found as a green stain on chalcopyrite in many of the veins although it is quantitatively unimportant. It is produced by the decomposition of chalcopyrite and helps to show that some of chalcopyrite may be confused with pyrite.

Rhodonite Only one vein containing rhodonite has been found in the mine (on the Tunnel Shaft 1st level). It is not associated with the molybdenite-quartz veins. Rhodonite can be distinguished by its darker red color and greater hardness, and is not soluble in HCl.

Sericite Sericite is not important in the deposit. It occurs mostly in the granite as an alteration product of feldspar. Some is also found in the orthoclase "gouge", but only in very small amounts.

Silver  Silver, like gold, is often reported in assays of ore and mill concentrates, and in samples of galena and chalcopyrite, but it is not of commercial value.

Gold  Gold is often reported as "traces" in assays of ore and concentrates, but never in large enough amounts to be of commercial value. Its association with other minerals is unknown, however in nearby prospects it is found in the pyrite.

Apatite  Apatite was reported by Larsen and Ross[1] but the writer was unable to find any. No one else at the mine could remember having seen any or having heard of any, so that the occurence must have been a very limited.

Hubnerite  Hubnerite was found only once as a few scattered crystals in the quartz of a vein.[2] The writer found several crystals in the quartz of a molybdenite-quartz vein in the Horseshoe prospect near the mouth of Red River Canyon. The veins found there are very similar to those of the Moly Mine.

## Mineral Paragenesis

The paragenesis was determined from megascopic relationship, then confirmed by thin section and polished

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[1] Larsen and Ross, "The R and S Molybdenum Mine" Econ. Geol., vol. 15, p. 71, Nov., 1920.

[2] Vanderwilt, "Geology of the Questa Molybdenite Deposit", Colo. Sci. Proc., vol. 13, no. 11, p. 629, 1938

section study. Quartz was the first vein mineral, followed by the main ore deposition of intergrowths of biotite and molybdenite with associated quartz and pyrite. Pyrite, chalcopyrite, galena, and sphalerite were deposited next, always occuring together and cutting the earlier minerals; later fluorite replaces quartz and fills in the cavities left in the veins. The fluorite is earlier than the final vein deposition of calcite and rhodochrosite since angular brecciated fragments of fluorite are found in the calcite-rhodochrosite veins. These veins occupy the central portion of the molybdenite-quartz veins and also cut all other mineralization.

At certain points in the mine this sequence is repeated so that the relationships are obscured, indicating that deposition took place for awhile, then earlier minerals were deposited again after the character of the solution had changed to its earlier form.

The surface exposures and the upper few feet of the veins are oxidized to molybdite and limonite.

The paragenic relationships of apatite, gold, silver, graphite, hubnerite, and rhodonite are unknown because of the small amounts of each that are present. Chlorite, orthoclase, sericite, and the clay minerals were formed

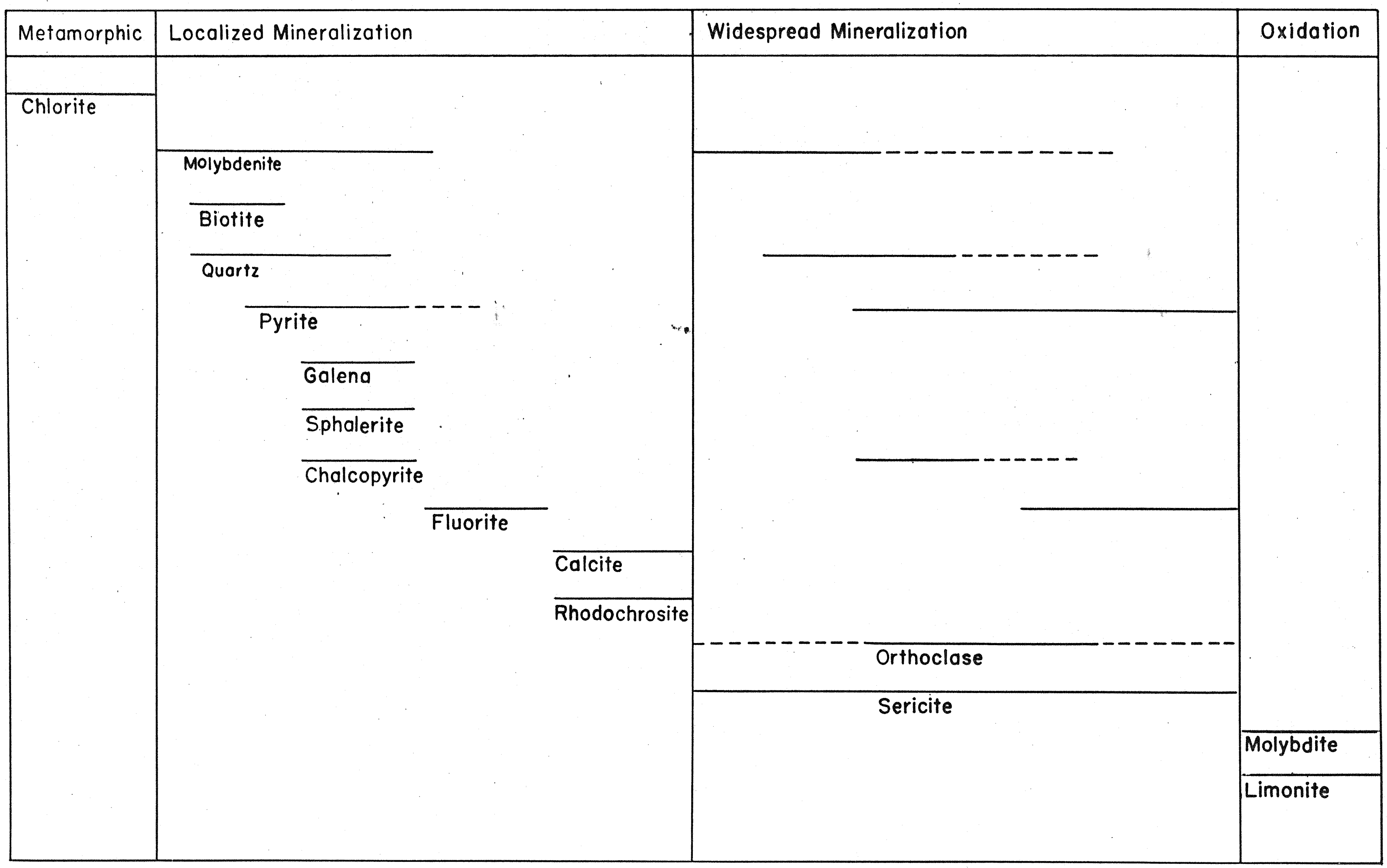



Figure 8. Stages of Mineralization in the Questa Molybdenite Deposit.

by later alteration in the veins and wall rock.

Grade of the Ore

Ore mined in the early operations averaged 8% molybdenite; some veins contained nearly pure molybdenite for short distances but this is not common. The present ore averages 1% molybdenite. Wall rock causes some dilution; sorting in the stopes and at the surface brings up the grade slightly. However, these factors counterbalance each other.

Form and Location of the Ore Bodies

The molybdenite occurs principely in veins; very little is found disseminated through the wall rock. The veins are largely quartz and molybdenite, although fluorite, pyrite, chalcopyrite, and rhodochrosite are locally abundant. The veins are narrow, ranging from film-thin to seven feet and averaging 6 to 18 inches in thickness.

The width of a typical vein varies greatly over short distances, the ore shoots being found where the vein thickens. Veins less than six inches thick are not commercial under present conditions. Two types of ore shoots are found. The first type are usually longer along the strike than down dip. These ore shoots are largest where the granite contact is steep; they may extend over 2000 feet along the strike and over 500 feet down dip with a thickness of five feet. Where the contact has a gentle dip the ore shoots are smaller, a typical one extending 500 feet along the strike and 300 feet down the dip with a thickness of two feet. A second group of ore shoots are controlled by the intersection of cooling fractures, a typical one extending 10 feet along the strike and 100 feet down dip with a thickness of two feet. All the ore shoots are lenticular, and occur at random throughout the mine.

The veins occur along the east-west striking portion of the contact between the Sulphur Gulch granite stock and the "greenstone complex". When the strike of the contact is north and south very few veins or ore shoots have been found. The east-west portion of the contact is over 2000 feet long at the surface and only 700 feet long on the Tunnel Shaft 1st level. Most of the veins follow the contact, the others are in the granite within 100 feet of the contact and are roughly parallel to it. A few veins dip to the north. Most of the ore shoots are in lenticular veins on the contact. These veins are not continuous but are replaced by other veins both laterally and down dip. The veins in the granite generally converge toward the contact in depth and either follow the contact or pass into the softer greenstone where

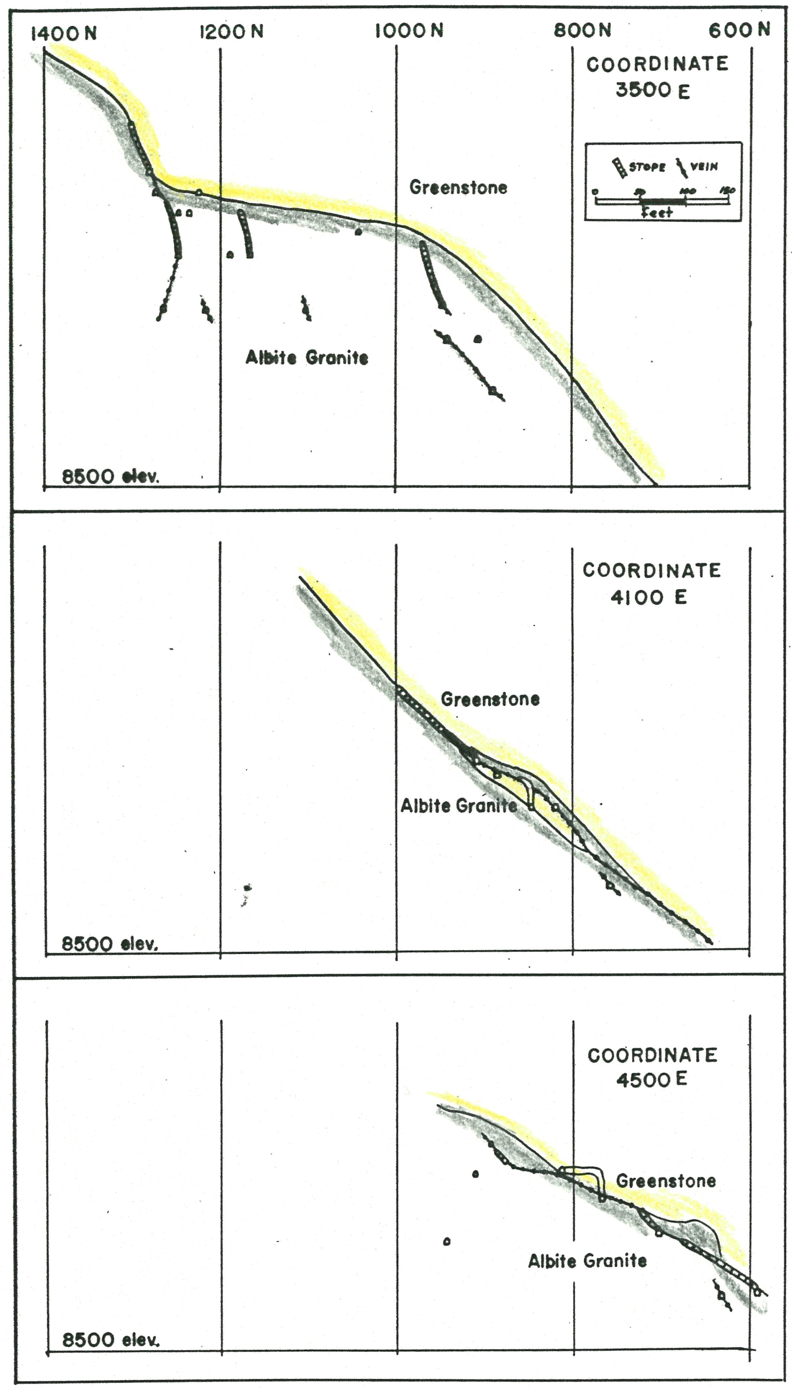



Figure 9. Typical Cross Sections Showing the Relationship of the Veins to the Contact.

where they pinch out. If a vein is along a steeply dipping contact and the dip flattens, the vein usually continues at the steeper dip and dies out in the granite. If an upward bulge occurs in the granite the vein on the contact commonly cuts across the bulge. When a vein passes into the greenstone it invariably pinches out. If it leaves the contact and passes into the granite it often divides into a "horsetail".

Many veins have one well defined wall; the other wall is marked by many small veinlets, each containing a film of molybdenite, which are scattered through the wall rock. In some places a vein will split into parallel veins only a few feet apart, then join again. Often a thick vein will pinch to a film-thin layer then open into a thick vein again or stpp completely.

Two sets of fractures control the form and location of the ore bodies. One set of fractures strikes east-west and dips to the north at about 50°. These fractures are regional and are not confined to the area around the mine. The other set is parallel to the granite-greenstone contact and is located only in the granite in a zone along the contact; these apparently formed when the granite cooled. The principal mineralization occurs where the strikes of the

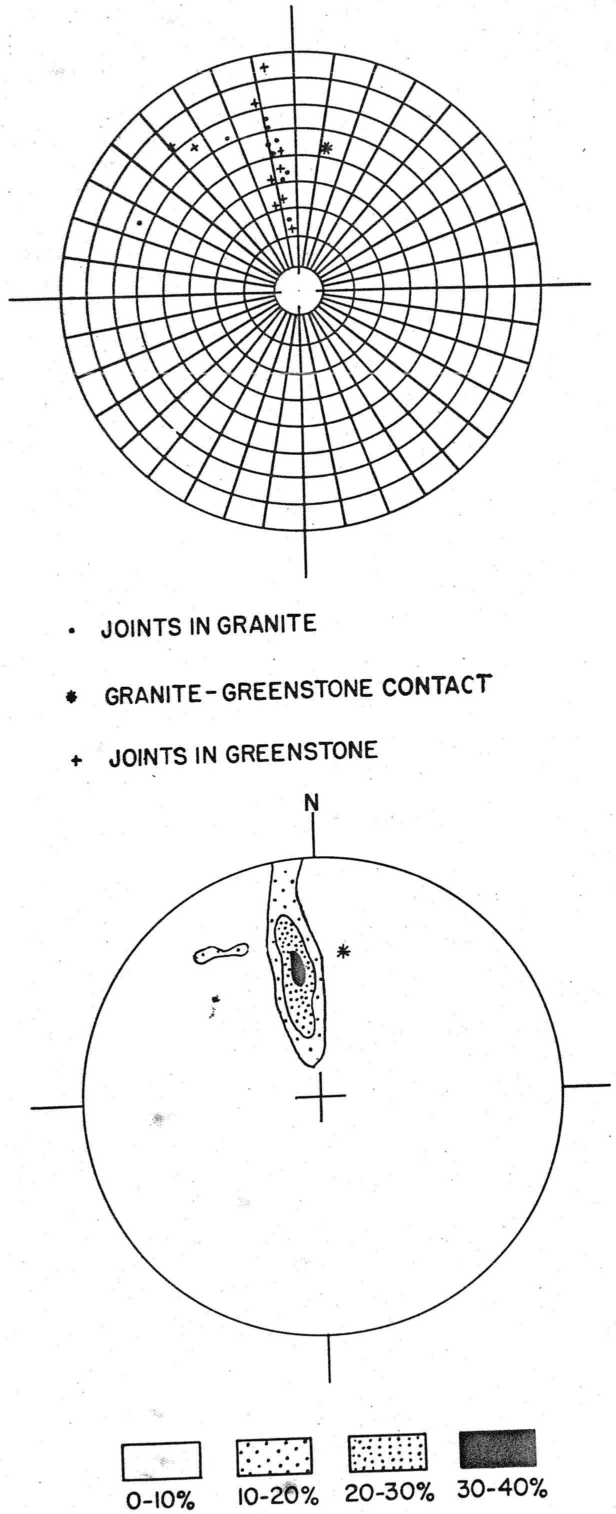
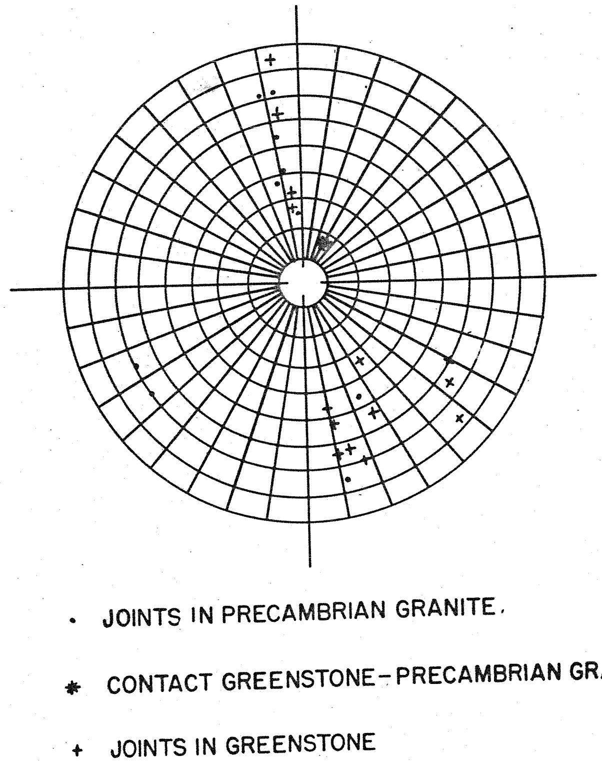



Figure 10. Point and Contour Diagrams of 20 Joints in the Mile Long Adit of the Moly Mine at the Granite-Greenstone Contact. (See Structural Geology by Billings, page 340, for an explanation of this type of diagram.)



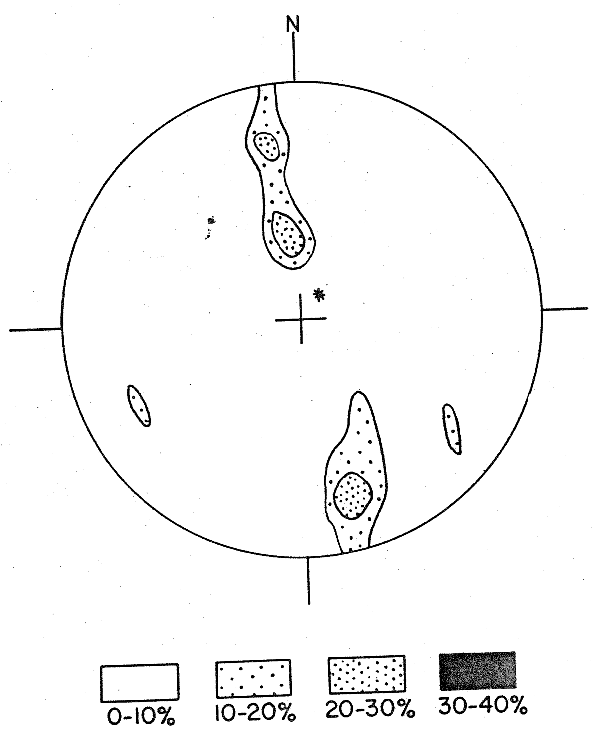
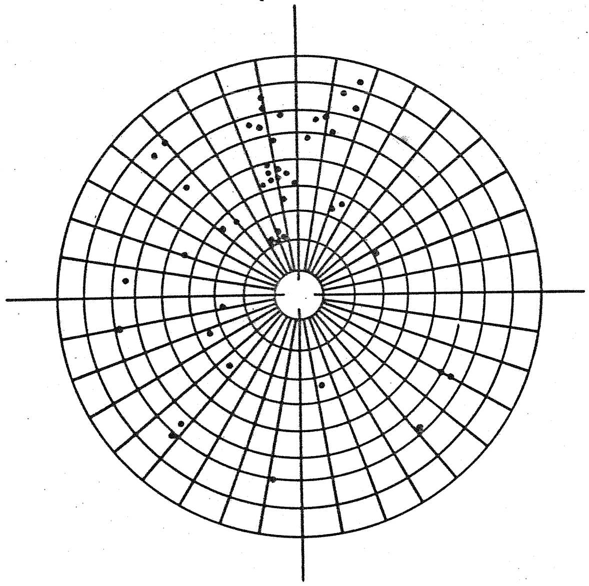




Figure 11. Point and Contour Diagram of 24 Joints at Precambrian - Greenstone Contact in the Mile Long Adit of the Moly Mine. Plotted on the upper hemisphere of a equal area projection.



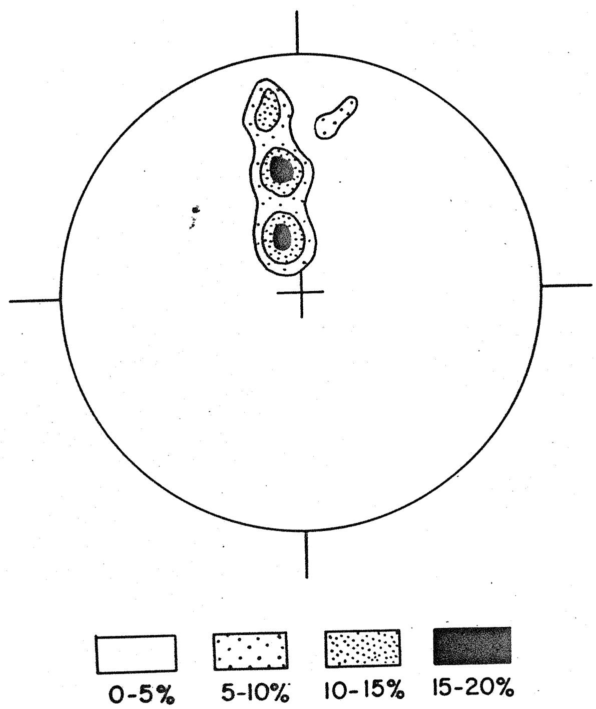



Figure 12. Point and Contour Diagram of 48 Joints 1400 feet south of the Precambrian-Greenstone Contact and 2400 feet south of the Granite-Greenstone Contact in the Mile Long Adit of the Moly Mine.

two set of fractures are parallel and the dips opposite, and the fractures in the granite were reopened as channels for the ore solution. The north dipping fractures are sealed by the soft greenstone. The ore solutions were thus confined and the minerals deposited in the granite. The writer plotted the strikes and dips of the fractures taken at different points along the Moly Tunnel, on equal area projections. It was possible to take points at distances as far as 4000 feet from the granite-greenstone contact and in the granite, greenstone, and granite gneiss; all three are present in the adit. At each point where fractures were measured there were a large group of fractures belonging to the east-west striking, north-dipping group. The older the rock, the larger the percentage of fractures which did not belong to this group; the older rocks have been subjected to more fracture-producing forces than the younger rocks. The greenstone near the contact with the granite gneiss is fractured along an east-west strike but dip to the south; their origin is unknown. The granite-greenstone contact dips north in the adit obscuring the difference between the regional fractures and the cooling fractures. The value of this study is greatly limited by the relatively small number of joints measured and the reversed dip of the granite-greenstone contact. More comprehensive measurements underground and on the surface would require considerable time, but might add much to the understanding of the ore localization.

## Changes in Wall Rock Composition

### Silicification

A minor amount of silicification occurs along the molybdenite-quartz and quartz veins but usually does not extend more than a few inches from the vein. This apparently is a replacement of the rock by quartz and occurs only in the granite.

At several points in the mine large areas of granite have been silicified, the granite appearing gray instead of the usual pink. Thin section study shows that the rock has orthoclase and albite phenocrysts in a groundmass of quartz, and differs from the ordinary porphyritic granite in that the groundmass is nearly all quartz rather than equal amounts of quartz and feldspar.

### Chloritization

The biotite in both the greenstone and granite has been altered to chlorite. The rocks along the contact of the granite were probably altered by hydrothermal action. The alteration of the biotite in the veins took place later, probably at the same time as the ore mineralization stage.

### Montmorillonization

Some of the feldspar in the granite has been altered to montmorillonite. It appears that this alteration is confined to zones near fractures and joints, for commonly it is not found in the more solid rock and was not found in thin sections of the granite taken from the walls of veins within a few inches of the ore.

### Other Changes

Deposition of disseminated pyrite occurs along the veins. The feldspars in the granite show some alteration to sericite.

## Genesis

### Manner of Emplacement

The minerals of the molybdenite-quartz veins were deposited as cavity filling by solutions that penetrated the rock along fractures. Little replacement of wall rock occured.

### Source of the Ore-forming Solutions

Most molybdenite deposits, including that at the Moly mine, are associated with granodiorite suggesting a genetic relationship. The albite-rich granite approaches granodiorite in composition and could be considered as such although the term "albite-rich granite" is more descriptive. The molybdenite and other minerals were probably derived from solutions which emanated from the magma chamber after the upper part of the stock had solidified.

Physical Conditions of Deposition

Molybdenite is considered to be an indicator of high temperature deposition, galena and chalcopyrite of intermediate temperatures, and rhodochrosite of low temperatures. The relative ages of these minerals in the mine indicates that the solutions were introduced at high temperatures and pressures. Most of the molybdenite was deposited during the early period of high temperatures and pressures, and the other minerals precipitated during the subsequent periods of decreasing temperature-pressure conditions. However, the evidence does not allow a specific determination of the pressure-temperature relationships.

Causes of Ore Deposition

[illegible], [illegible], Mo, [illegible], [illegible], and [illegible] were present in relatively large amounts, while K, Al, [illegible], [illegible], [illegible], [illegible], [illegible], Au, and Ag were present in smaller amounts. Reduction of the temperature and pressure of the ore-forming solutions seems to be the main cause of deposition. The granite through which the ore solutions passed was relatively cool since cooling fractures had formed. Changes in pH have not been an important factor since wall rock alteration is slight and earlier minerals are lacking for reaction.

## Classification
### (According to Lindgren)

The Moly Mine deposit can be classified as hydrothermal of hypothermal to mesothermal intensity (according to Lindgren's classification). Molybdenite and biotite are typical minerals of high temperature deposits, while galena, and sphalerite are somewhat lower temperature. Telescoping is indicated by the deposition of high and low temperature minerals at the same spot in the veins.

There is only one other commercial cavity-filling molybdenite deposit, Copper Creek, Arizona. In this deposit two sets of vertical fractures intersect at right angles, forming a pipe-like body.

Other types of commercial molybdenite deposits are:

Pegmatite - Moss Mine, Quebec.
Contact metamorphic - Azegour, Morocco; Yetholme, New South Wales; Renfrew, Ontario; Helvetia, Ariz.
Disseminated replacement - Climax, Colo.; Urad, Colo.; Cananea, Mexico; Braden, Chile; Bingham Canyon, Utah, Santa Rita, N. M., and other porphyry copper deposits of southwest U.S.

## Other Prospects

### In Albite-Rich Granite

Bear Canyon (Horseshoe) Claims  Molybdenite-quartz mineralization is found in prospects on the Bear Canyon claims (see Fig. 13) which are in the albite-rich granite

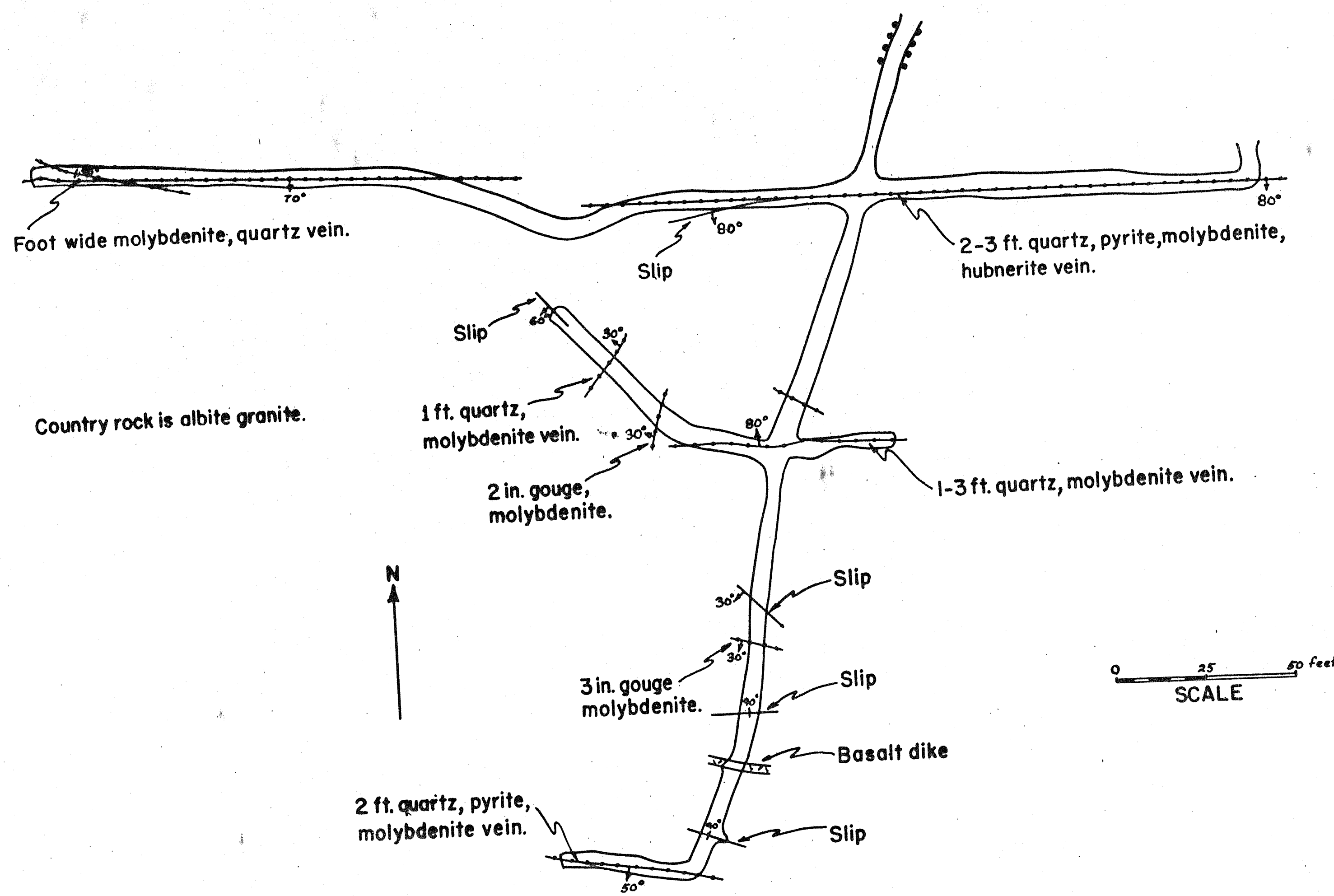



Figure 13. Geology of the Prospect on the Horseshoe No. 6 Claim. (see Fig. 3)

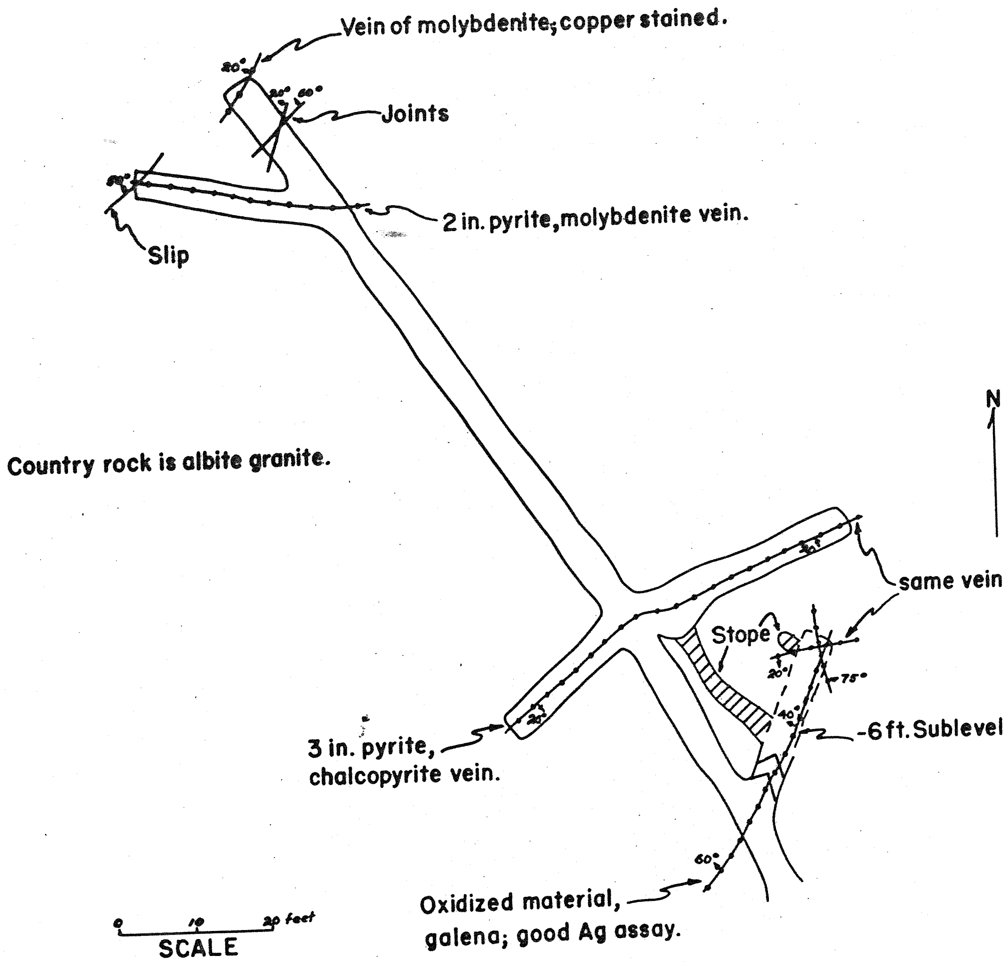



Figure 14. Geology of the Bernhardt Prospect.

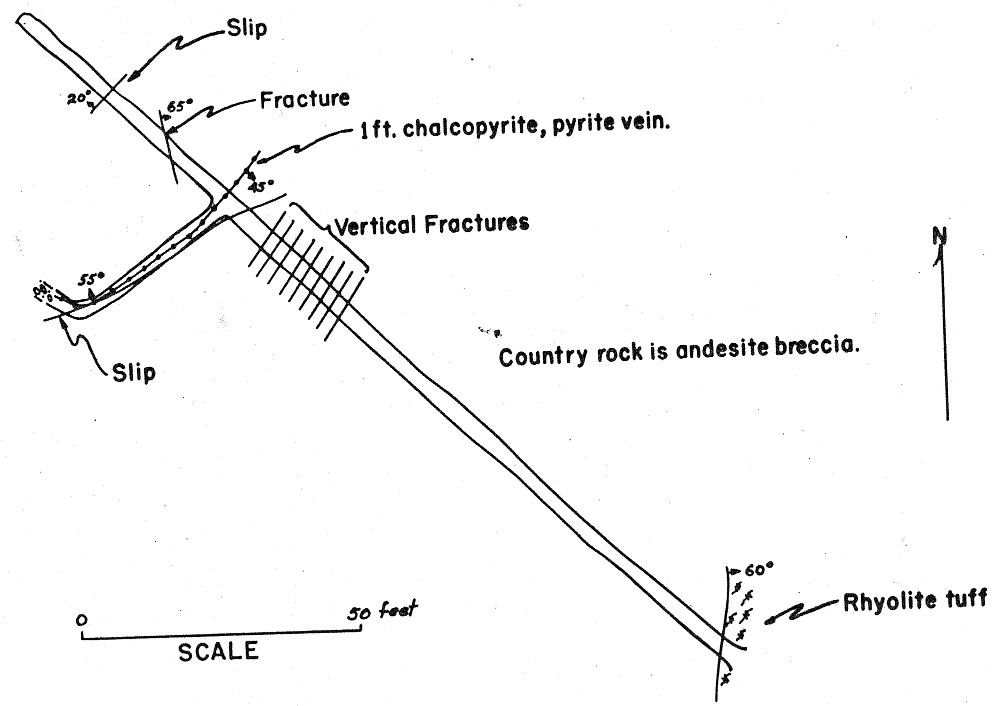



Figure 15. Geology of the Hawk Tunnel; the Northern Most BJB Prospect in Goat Hill Gulch.

stock at Flag Mountain; to date the showings are not commercial.

Bernhardt Claims   Leroy Bernhardt owns a group of claims along Sulphur Gulch south of Z tunnel. The prospects on these claims are in the Sulphur Gulch granite stock. Silver ore, with associated quartz, pyrite, galena, sphalerite, and hematite occurs in small irregular fractures in one of the prospects (see Fig.14). Samples giving assays of 50 ounces of silver per ton were found. However the vein had no horizontal or vertical extent. Molybdenite is found only in small amounts, usually as thin films along fractures.

In Rhyolite

BJB Prospects   Three prospects are located along Goat Hill Gulch in the rhyolite flows. Some molybdenite was mined from the southernmost prospect and was milled at the Moly Mine Mill. The winze from which the ore was mined is now filled so that the occurence could not be mapped. In the northernmost prospect, the Hawk Tunnel, a good vein of chalcopyrite was encountered (see Fig. 15), but working the prospect proved to be too expensive because of the difficulty of hauling ore down the gulch. Green fluorite is also abundant; the mineralization occured during the formation of the altered areas.

# MINING

## Description of the Mine

The Moly Mine consists of about 33 miles of workings ranging over 1100 feet vertically. The mine is divided into three parts, the "Highline-Blind Gulch workings", the "Sulphur Gulch South workings", and the "Tunnel Shaft workings". The relationship of the levels to each other and the geology is shown in Plate 1 (see pocket at back).

### Highline-Blind Gulch Workings

The Highline-Blind Gulch workings are located under Highline Ridge north of Sulphur Gulch and west of Blind Gulch, and include the Highline Tunnel, Blind Gulch Tunnel, and B, C, and D Levels, as well as many shorter levels. Most of the adits are caved so that a study of the underground geology is impossible.

### Sulphur Gulch South Workings

The Sulphur Gulch South workings include all the workings south of Sulphur Gulch which have been mined through adits along the Gulch. They include the following main levels:

| | | elevation |
|---|---|---|
| Old Glory Hole Workings - Upper Drift | | 8864 ft. |
| No. 3 Level | | 8629 |
| W Level | | 8605 |
| 100 Foot Level Z Tunnel | Mined through raises from Z Tunnel Level | 8561 |
| 58 Foot Level Z Tunnel | | 8555 |
| 50 Foot Level Z Tunnel | | 8504 |

| | | elevation |
|---|---|---|
| | | 8441 ft. |
| Z Tunnel Level | Mined through Z Winze to Z Tunnel | 8401 |
| Z Winze, 35 Foot Level | | 8305 |
| Z Winze, 1st Level | | 8208 |
| Z Winze, 2nd Level | | 8158 |
| 2nd Winze, 3rd Level | Mined through 2nd Winze and Z Winze to Z Tunnel | 8108 |
| 2nd Winze, 4th Level | | 8007 |
| 2nd Winze, 5th Level | | |

Tunnel Shaft Workings

The Tunnel Shaft workings include the levels below the 2nd Winze, 5th Level which are mined through the vertical winze known as the Tunnel Shaft, and the Moly Tunnel whose portal is along Red River. It includes the following main levels:

| | elevation |
|---|---|
| Tunnel Shaft 1st Level | 7908 ft. |
| Tunnel Shaft 2nd Level | 7814 |
| Southwest Incline, Sublevels | 7784 to 7769 |

Prospecting and Exploration

The veins do not form bold outcrops since they are softer than the country rock. However, exposures are bright canary-yellow with molybdite.

Underground exploration is done more or less blindly, although these factors are used as guides:

1. Economically important ore bodies are found along the granite-greenstone contact.
2. Mineralization is weak in the tight greenstone and strong in the more open granite.
3. Most of the ore is found where the contact strikes east.
4. Veins are thicker when the contact dips steeply.

When ore reserves become low, prospecting is carried on by drifting along a fracture coated with "paint",[1] or by cross-cutting to intersect other veins, or by exploring the granite-greenstone contact at a new level. Diamond drilling has never been tried.

Electrical (resistivity) prospecting[2] has been tried (in 1927). Good ore was found in several places indicated by the survey, but many of the indications turned out to be cavities and gouge zones containing water.

## Development

The mine is developed by adits, raises, winzes, and drifts at different levels; the vertical interval between levels range from 15 to 100 feet. All development work is on a contract basis.

### Drifting

Most drifts and crosscuts are 4½ by 6½ feet in section and are untimbered except in some places along veins or in badly fractured rock (see Plate V). Only about 25% of the workings have been timbered.

Light drifter-type machines drilling a 7 to 8 hole toe-

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1 Paint is a term used by the miners to describe a very thin coating of molybdenite found along a fracture.

2 Sundberg and Nordstrom, "Electrical Prospecting for Molybdenite at Questa, New Mexico", Geophysical Prospecting, AIME, pp. 125-127, 1927.

cut round are ordinarily used for level development. The rounds are loaded with 26 or 27 sticks of 1 by 8 inch, 40% gelatin dynamite and normally break 4 feet. Mucking is done by hand into 12 or 14 cubic foot cars, then hand-trammed to the raise.

Some of the drifting in soft ground is done by "single jacking" (hand drilling), using four pound single-jack hammers and four gages of chisel-point drill steel. Hand-drilled rounds have no standard form; the miner places the holes to take advantage of the joints in the rock. A round breaks 3 feet, producing an irregular shaped drift.

Timber used is native Douglas fir and some white spruce. Most of it is cut from nearby burnt-off areas and is well seasoned.

## Raising

Raising comprises about one-fifth of the development footage. Raises are of two types, cribbed and stulled, and may have one or two (manway and ore chute) compartments. Only a few are vertical.

Machine-drilling is done with stopers. Center V-cuts are used in the two-compartment raises, and end-cuts in single compartment raises. Blasting is the same as in the drifts.

## Mining Methods

About two-thirds of the ore is mined by cut-and-fill stoping and one-third by open stoping. Several factors favoring cut-and-fill stoping are:

1. Usually the ground needs the support given by filling.
2. Because of the narrow width of the veins, it is often necessary to break some country rock to give working space, and the resulting waste is most cheaply disposed of as stope fill.
3. Sorting in the stopes in order to reduce the amount of tramming results in waste which is used as fill.

Open stoping is used in firm, hard rock where veins have a gentle dip. Its advantage is the complete recovery of ore; none of the fines is lost in the fill as happens during cut-and-fill stoping, and the saving in time and expense of timbering is important.

### Cut-and-Fill Stoping

Development A cut-and-fill stope is started by taking a cut from the back of the drift, placing drift sets and lagging, and then building chutes. Grizzlies are not needed at the top of the chutes since all the ore is worked over in the stopes.

Drilling The ground is broken by holes drilled almost straight into the back. Only a small section of the back is drilled at one time, and the holes are seldom more than 3 feet deep.

Breaking Methods Various methods are used to break the ore; in wide veins where no breaking of the wall is needed, picking or light shooting is used. In narrow veins, the foot-wall is broken away from the ore and the ore is shot down separately. The ore shoots are so irregular that stoping methods must be varied with each round. If the ore is too loose to stick to the hanging wall, it is brought down with the waste and sorted. If the ore is in streaks along both walls, the waste between is often removed first.

Blasting and Timbering Planking is sometimes laid to prevent loss of ore in the fill, but often the fill is leveled and covered with fine waste. Shooting is done at noon or the end of the shift unless good ventilation makes it possible to blast at anytime. Loose parts of the back are then temporarily supported by stulls.

Sorting and Loading The ore is nearly always hand-sorted and screened in the stopes. The sorted ore is then shoveled into chutes, the waste being placed as fill to support the hanging wall. The chutes are carried upward by adding cribs.

Open Stoping

Open stoping is usually used in flat dipping veins. This method is often used when the ore is known to be limited or doubtful extent. Often chutes are not installed, the ore and waste being shoveled into the cars and sorted at the surface. Stulls are used on a large scale to support the hanging wall. The method of breaking is the same as in cut-and-fill stopes.

## Underground Haulage

Ore is hand-trammed to the Tunnel Shaft in 12 or 14 cubic foot, box-body, end-dump cars which hold about 1500 pounds of ore. Waste and ore from the 2nd Level Sublevels is first pulled by cable up the Southwest Incline, then hand-trammed to the Tunnel Shaft.

After the cars are hoisted up the shaft, they are dumped into larger cars which are hauled to the surface ore bins by a storage battery engine which operates in the mile-long Moly Tunnel and on the surface trackage. This engine also hauls men and supplies.

## Drainage

All the levels above the Moly Tunnel are drained by gravity out the adits. The Tunnel Shaft workings drain into two sumps; one at the bottom of the Tunnel Shaft, the other at the bottom of the Southwest Incline. Water from the sump in the Incline is pumped up to the Tunnel Shaft 2nd Level then flows by gravity into the sump in the Tunnel Shaft. Water from the Tunnel Shaft sump is pumped up the shaft, then flows by gravity out the Moly Tunnel.

## Ventilation

Ventlation is natural and is accomplished by a system of raises, drifts, and crosscuts which are kept open. Existing drifts, crosscuts, manways, and ore chutes are utilized although many raises have been driven solely for ventilation.

# MILLING

## Preliminary Sorting

A sorting bin is located at the dump near the portal of the Moly Tunnel. The track from the mine runs over the top of the bin. If the ore needs no sorting, it is dumped directly into the bin from the mine cars. If sorting is necessary, the ore is dumped onto a screen. The large chunks slide onto a sorting platform, and the fines drop into the ore bin. On the sorting platform the pieces of ore are picked out by hand and thrown into the ore bin. The waste is then shoveled into cars on the waste track and trammed to the dump.

## Transportation to the Mill

A contract trucker hauls the ore to the mill over State Highway 38, a well graded dirt road, which passes the mill and ore bin. The truck haul is 1.3 miles, with an uphill climb of 220 feet in that distance.

The mill was built on its present site when the ore was being hauled downhill from the Sulphur Gulch South workings. With the opening of the Moly Tunnel, the mill site has become unfavorable , requiring an uphill haul. However, the cost of moving the mill to a better site would be excessive unless large reserves of ore were found.

## The Mill

The mill is housed in the same building that was used for the equipment of the 1930 mill. The building is of frame contruction, with concrete foundations and floors. The mill has a capacity of 50 tons per day, although much smaller amounts are often milled.

## Milling Operation

### Mill Feed

Two types of material are milled: (1) ore direct from the mine, and (2) tailings from the older of the two tailing ponds. The ore from the mine is kept in coarse ore bins and fed to a jaw crusher over a grizzly. The tailings are loaded into dump trucks by a power shovel and hauled a short distance to the tailings bin where they are stored, to be fed directly to the ball mill. The tailings average 0.55% $MoS_2$.

### Coarse Crushing

The jaw crusher crushes the ore to minus 1½ inch which is delivered to the fine-ore bin along with the undersize from the grizzly.

### Grinding

The ore from the fine-ore bin or the tailings bin (whichever is being milled) is fed to a ball mill which is

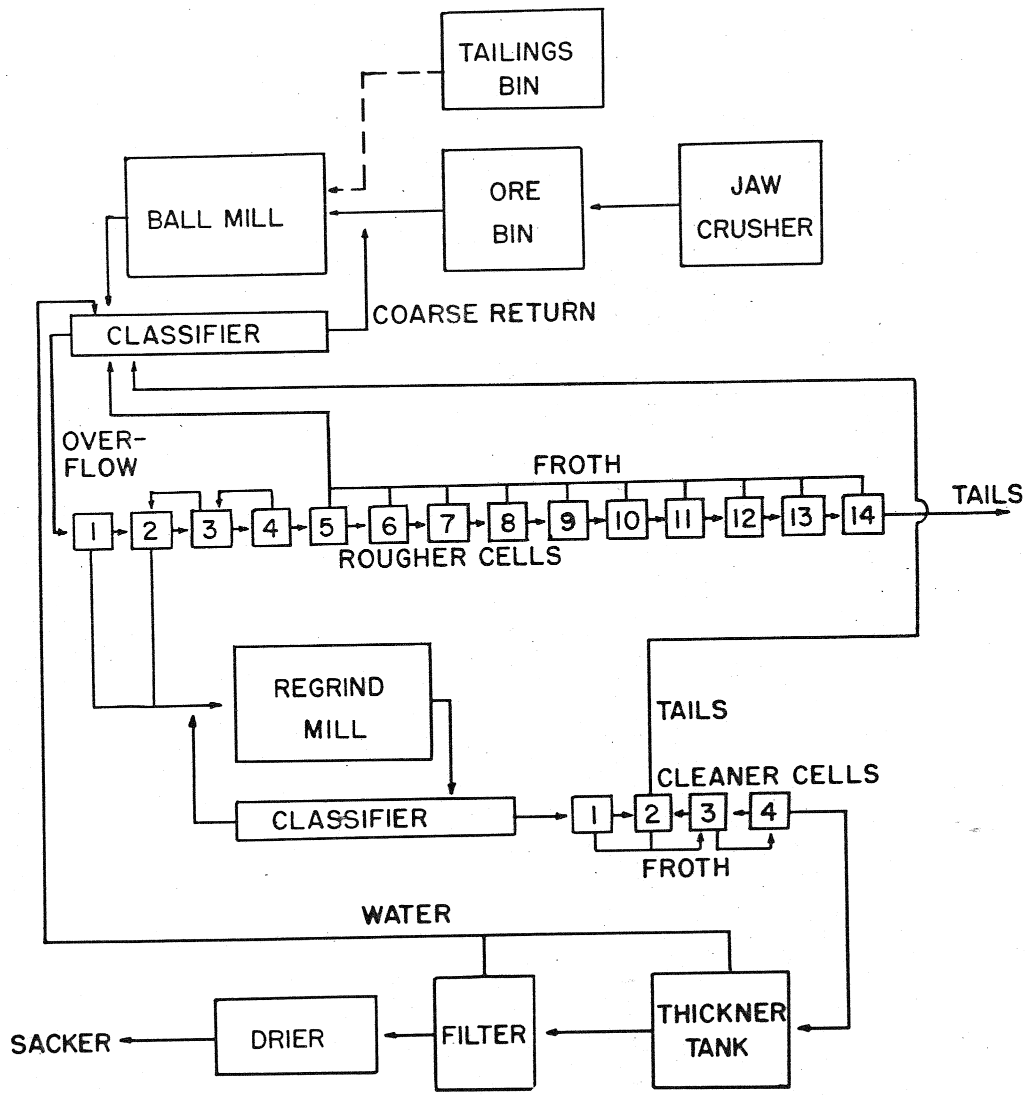


Figure 18. Flow Sheet of the Moly Mine Mill as Operated on August 20, 1950.

in a closed circuit with a classifier. The overflow from the classifier goes to the rougher cells.

## Flotation

Fourteen rougher cells are used to remove most of the waste as tailings. Between the rougher cells and the cleaner cells a regrind mill is used in a closed circuit with a classifier; the overflow from the classifier goes to the cleaner cells. The four cleaner cells send the heads back to the ball mill to be reground.

TABLE 2

MILL REAGENTS USED DURING THE YEAR ENDING MAY 29, 1950[1]

| Reagent | Units | Quantity | Unit Price | Total Price |
|---|---|---|---|---|
| D-23 Frother | gals | 320.5 | $1.3525 | $433.48 |
| B-53 Frother | gals | 20.3 | 1.5745 | 31.88 |
| DR 744 | lbs | 240 | .2836 | 68.06 |
| Methyl Isobutyl Carbinal | gals | 215.5 | 1.2404 | 267.30 |
| Pine Oil #200 Pensacola | gals | 248.74 | 1.2602 | 313.46 |
| Reagent #505 | lbs | 200 | .2593 | 67.40 |
| Soda Ash | lbs | 6300 | .0519 | 326.52 |
| Soda (Caustic Flake 76%) | lbs | 255 | .0873 | 22.26 |
| Sodium Cyanide | lbs | 1435 | .1832 | 262.52 |
| Sulphuric Acid | gals | 26.0 | 1.2556 | 32.65 |
| Utah Fuel Oil (Conoco) | gals | 150 | .4480 | 71.23 |
| | | | total | 1894.21 |

## Tailings Disposal

The tailings from the flotation cells is pumped to the tailings pond by a sand pump. A low retaining wall is piled

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1 Information supplied by Bill O'Toole, mine clerk.

up around the edge. The tailings settle to the bottom of the pond and the clear water flows through a stand pipe located in the middle of the pond which discharges into Red River.

<u>Dewatering</u>

The heads from the cleaner cells contain over 95% water. Some of this water is removed in the thickener tank which decreases the water to 75%. Most of the remaining water is removed by filtering.

<u>Handling the Concentrates</u>

The heads, which still contain about 10% moisture, are pulled through a dryer by a worm-drive feed. The dried concentrates are fed into paper-lined burlap sacks which hold about 80 pounds. The bagged concentrates average 80% $MoS_2$. The sacks are shipped to the company refinery at Washington, Pennsylvania.

## Power

Power for the milling operations is supplied by a water wheel and diesel engine which are connected by belt to the main drive-shaft through jaw clutches. A system of belts supplies power from the main drive-shaft to the different operations. A two phase REA powerline is used to supply electricity when the mill is shut down.

The water for the water wheel is diverted from Red River by a small rock dam and is carried a distance of 6800 feet by a flume. This flume has a grade of 0.15%, giving a velocity of 4 ft/sec and a flow of 14 second-feet. The water from the flume drops from the penstock to the wheel through two 16-inch pipes which are joined in a short 20-inch section at the wheel and develop a head of 110 feet.

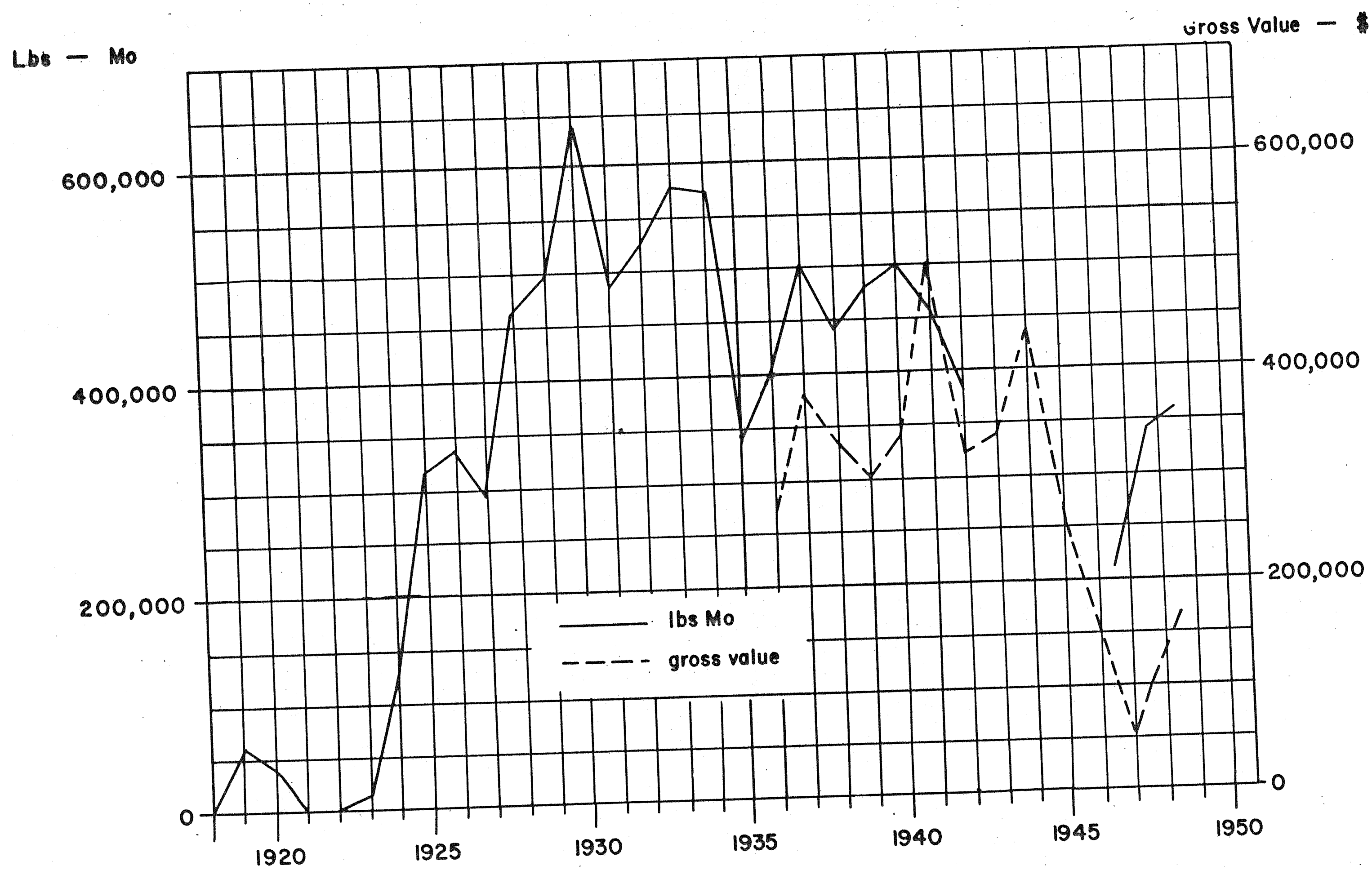


Figure 19. Production of the Questa Molybdenum Mine. (Data from the Mineral Yearbook and Molybdenum Corporation of America records.)

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