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Bulletin _____

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SUBJECT TO REVISION

MOLYBDENUM RESOURCES OF NEVADA

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193 p

INTRODUCTION

Purpose and Scope

This bulletin briefly describes ~~each~~ occurrences of molybdenum minerals in Nevada; compares these occurrences to one another and to other deposits of the world; describes their geographic distribution and relation to other geologic features; and gives guides for exploration. It also provides background information on the history, uses, mining, concentration, processing, marketing, present production and consumption, future outlook, and resources of molybdenum in the State and world. It completely supersedes Nevada Bureau of Mines Report 2, An inventory of molybdenum occurrences of Nevada.

The bulletin brings together the extensive, scattered data on molybdenum in Nevada. Much unpublished information is included that would not be readily available otherwise. It is intended to be a summary, and no attempt was made to include all the available information. Sources of more detailed data are cited in the text.

It is hoped that the information herein will provide a foundation for more detailed studies that will lead to the discovery of minable molybdenum deposits, as well as deposits of associated mineral commodities. I will appreciate receiving information about other molybdenum occurrences in Nevada, as well as additional data or corrections for the occurrences described.

Methods of Investigation

The geology of molybdenum has been one of the writer's special interests for some years (Schilling, 1956, 1962, 1964, 1965). This study is the outgrowth of a literature search which lead to the preparation of an inventory of molybdenum occurrences in Nevada (Schilling, 1962a) and a map showing their location (Schilling, 1962b). For this project, all occurrences that could be

located were examined, including a number that are not in the inventory. Data from the field examinations and laboratory studies of material collected in the field, as well as published and unpublished information from a variety of sources, were summarized for each occurrence. Individual punch cards were then prepared, making it possible to readily compare the occurrences to each other and to other geologic features in a variety of ways. Punch cards, based in many cases on personal examinations, had previously been made for most of the major, and many of the minor, molybdenum deposits throughout the world; these cards also were compared to those of Nevada occurrences.

Previous Work

Numerous publications mention molybdenum occurrences in Nevada or describe the geologic setting in which they occur. These are cited at appropriate places in the text and listed under ~~References~~ Bibliography. Many contain more detailed information than is given in this report. The reader also is referred to the general references: Nevada Bureau of Mines, 1965; Gianella and Prince, 1945; Lincoln, 1923; and Webb and Wilson, 1962.

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ECONOMICS

History

The word molybdenum is derived from the Greek word molybdaina, meaning leadlike. This term plus the later modifications such as molybdena, molybditis, molybdos was applied to all soft, leadlike materials, including the minerals now known as galena, graphite, stibnite, and molybdenite. Still later, the word molybdaena was used to mean only graphite and molybdenite. Today, molybdenum (and molybdenite) often is called simply moly.

In 1778, Karl Scheele, the Swedish chemist for whom scheelite was named, identified molybdenite as a distinct mineral (Scheele, 1778). Four years later, in 1782, J. J. Hjelm isolated the metal itself. The Knaben mine in southern Norway probably produced small amounts of molybdenite as early as the late 18th or early 19th century. Molybdenum was then being used in certain chemicals and dyes.

In 1894, Schneider and Company of France used molybdenum as an alloy in making steel armor plate. The first commercial use of molybdenum as an alloy was in 1898, when the Sanderson Steel Company of the United States began producing self-hardening molybdenum tool steel. Although this use stimulated considerable interest, the erratic performance of the early molybdenum tool steel due to improper heat treating discouraged further development of molybdenum as an alloying element.

Molybdenum production remained small and sporadic until World War I (fig. _). Molybdenite was mined in the Knaben area of Norway and from several areas in Australia. Wulfenite was produced in Arizona and New Mexico. In 1913, the Kvina mine in Norway began using a flotation method to recover molybdenite, making it possible to exploit lower grade and more complex ores.

Figure __. World production of molybdenum by countries (Russian and Chinese production estimated).

At the start of World War I, total world production of molybdenum amounted to 200,000 pounds a year. During the war, increasing demand for the new alloying metal led to extensive exploration, reopening of old mines, and opening of new ones. The Climax mine in Colorado, the Questa molybdenum mine in New Mexico, and the Moss mine in Canada were brought into production. By 1918, world production of molybdenum had risen to nearly two million pounds.

Large stockpiles and decreasing demand caused a collapse of the market for molybdenum at the end of World War I. Nearly all the mines had closed by 1921. Research efforts to develop peacetime uses for molybdenum were greatly expanded, particularly by Climax. The auto industries began to use increasing amounts of molybdenum steels, and the Questa and Climax mines were reopened in 1923 and 1925, respectively. These two mines dominated world production, producing 75 percent of the world's supply in 1925.

Except for a slump after World War II, world production of molybdenum has continued to increase rapidly since 1925 (fig. _). In 1933, the first by-product recovery of molybdenum from copper ores began at Cananea, Mexico. In 1936, molybdenum by-product recovery was started at the Bingham Canyon mine, Utah. In 1939, recovery of molybdenum as a coproduct of tungsten mining began at the Pine Creek mine in California. Many other copper mines in the United States, Chile, Peru, Canada and Russia now produce by-product molybdenite; Kennecott began recovering molybdenite from their open-pit mines at Ruth (near Ely), Nevada, in 1941. And large mines producing only molybdenite have been opened at Questa, New Mexico, Urad, Colorado, and at several locations in British Columbia, Canada.

Although molybdenum is still used mainly as an alloy in steel and iron, its use as a metal, in chemicals, and as a lubricant is expanding rapidly. By ~~1964~~ 1970, world production had increased to more than ~~100~~ 160 million pounds annually.

Properties and Uses

Molybdenum is a lustrous gray metal having a higher melting point (4730°F) than all the elements except carbon, rhenium, tungsten, and tantalum. It is somewhat heavier than iron, and slightly softer than steel. Chemically, it has valences of 2, 3, 4, 5, and 6 in stable compounds. Molybdenum does not occur free in nature. It has good thermal conductivity (about half that of copper), a high modulus of elasticity, and one of the lowest coefficients of expansion of all the pure metals. (Northcott, 1956).

While molybdenum finds numerous applications (Schneider, 1963, McInnis, 1957, as well as various publications of the Climax Molybdenum Co.), by far its largest use is an alloying element in upgrading iron, steel, and to a lesser extent nonferrous superalloys. It is one of the most versatile alloying elements and is extensively used to increase strength, hardness, and wear and corrosion resistance, particularly at elevated temperatures. It is a strong carbide-forming element, and much of its alloying effect is imparted through the formation of carbides. More than eighty-five percent of the molybdenum consumed in recent years has been used in alloys.

Con~~g~~ventional engineering steels, used in bridges, buildings, and such diverse items as submarines, pressure vessels, and power chovels, commonly contain 0.2 to 0.3 percent molybdenum combined with chromium and nickel. Steels have recently been developed which give minimum yield strengths up to 300,000 pounds per square inch. Such ultrahigh strength steels are used in airplanes, missiles, and other applications where maximum strength/weight ratio is needed; the most widely used alloy contains 5 percent molybdenum, 18 percent nickel, and 9 percent cobalt.

no such word -- do you mean shovels?

The addition of molybdenum is in most cases the best means of increasing hot-strength, not only in steel and iron but in the nonferrous superalloys. Practically all the steels used at temperatures up to 1000°F., as in power plants and petroleum refineries, contain 0.5 to 1.5 percent molybdenum.

And alloys have been developed for use at temperatures up to 2000°F.; these superalloys contain up to 10 percent molybdenum, and may have a base of iron, nickel, or cobalt. Chromium commonly is added to high-temperature alloys to confer oxidation resistance.

The addition of 1 to 5 percent molybdenum to stainless steels is essential if such steels are to withstand the corrosive effects of many industrial processes. Nickel-base alloys containing up to 30 percent molybdenum are being used where the alloy must resist corrosion by hydrochloric acid and other chloride compounds. The use of such alloys is increasing rapidly as more fabricators develop the know-how to produce the vessels, heat exchangers, and other equipment needed by the chemical industry.

Molybdenum-base alloys, where molybdenum is the major constituent, have many promising applications, particularly for metal-working tools. An alloy of molybdenum with 30 percent tungsten now used in the aerospace industry has a higher melting point than tungsten.

Molybdenum metal has a small (5 percent) but rapidly increasing use in the electronic, missile, and nuclear energy industries. Its use has been restricted in the past by high production and fabrication costs, and the difficulty of preventing excessive oxidation, particularly at high temperatures. In the electronic industries, molybdenum metal is used in electronic tube supports, cathodes, glass-metal joints, and ceramic-metal seals, in electrical contacts, and in thermocouples, where a high melting point, strength at high temperatures, low vapor pressure, low electronic emissivity, or low thermal expansion is needed. The metal has found wide use in nozzles, leading edges of control surfaces, re-entry cones, heat-radiation shields, pumps, and other missile parts that are exposed to high temperatures. Molybdenum also has been fabricated into heat exchangers, piping, and structural parts for nuclear reactors because of the metal's

ability to absorb thermal-neutron radiation and to withstand high temperatures. Sprayed molybdenum coatings on iron, steel, aluminum, and other metals are being used to decrease friction and wear --- for example on piston rings for automobiles.

Molybdenum compounds also have a variety of applications. Corrosion-inhibitive pigments (sodium, calcium, and zinc molybdates) have an advantage over traditional inhibitors such as red lead, zinc chromate, and iron oxide in being both non-toxic and white, and are finding increasing use in food-handling equipment and water tanks. Molybdenum-containing catalysts such as bismuth phosphomolybdate are most effective denitrogenizers and desulfurizers, and because of their long life and high selectivity are widely used in the petroleum refining and organic chemical industries. Pure molybdenum sulfide is a versatile lubricant that can not only reduce friction but reduce wear even under elevated temperatures and sustain high loads; molysulfide can be used alone or as an additive in other types of lubricants. Other applications are as a popular orange pigment (lead molybdate-chromate) called moly orange, as micronutrients (sodium molybdate or molybdic oxide) in fertilizers, and as various chemical reagents.

Mining

The methods used to mine molybdenum ore depend largely on the type of deposit. Nearly all the molybdenum presently being produced comes from low-grade, disseminated deposits. These deposits are universally mined by high-volume, mass-mining methods --- by open-pitting if the amount of barren overburden is not too great or by block-caving underground. Kennecott Copper Corporation's ~~Tripp and Veteran's~~ mines of Ruth (near Ely), Nevada, are benched open-pits with truck-skip haulage.

More selective, smaller scale methods are used in exploiting the vein and oxidized lead-zinc deposits. Open, room and pillar stoping was used at the Shenandoah mine, near Goodsprings, Nevada.

Concentration

In nearly all instances, the crude ore must be concentrated before it can be sold or turned into useful products. The method of beneficiation depends largely on which molybdenum minerals and, to a lesser extent, other ore minerals and gangue are present.

Molybdenite. Molybdenite is universally upgraded by flotation (McInnis, p. 26-36). When the molybdenite is a by-product of copper mining, a molybdenum-copper flotation concentrate commonly is first produced and the molybdenite then separated from the copper by selective flotation (Hernlund, 1961). At the Big Pine mine in California, much of the molybdenum is recovered by flotation; however, some molybdenum (mostly as molybdian scheelite and powellite) is present in the scheelite (tungsten) concentrate and is recovered by digesting the concentrate in an alkaline solution and precipitating the molybdenum as a sulfide. At a few mines, by-products are being produced from molybdenite ore. At Climax, Colorado, pyrite, huebnerite (tungsten), monazite, and cassiterite (tin) are recovered from the tails by gravity separation using Humphrey spirals, tables, and magnetic separators; at the La Corne mine, Canada, bismuth is recovered from molybdenite flotation concentrates by acid leaching. Rhenium is recovered from molybdenite concentrates during the roasting process used to produce molybdic oxide.

Wulfenite. No wulfenite presently is being produced. When wulfenite ores were being mined, they were beneficiated by gravity or flotation methods.

Oxides. Many deposits contain secondary molybdenum minerals but until recently these values had not been recovered. The first plant built to do so was completed at the Climax mine, Colorado, in 1966 (Lane, Bender, and Ranzio, 1971). This ~~new~~ facility ~~is~~ produced several million pounds of molybdenum annually before being closed. Selected tailings from the molybdenite recovery-plant, those that contain significant amounts of oxide molybdenum, were ~~are~~ treated. As most of the oxide values were ~~are~~ in the very-fine particles, this material was ~~is~~ separated from the coarser

tailings --- 5,700 tons per day of tailings ~~are~~ were reduced to 1,650 tons of concentrate. The oxide molybdenum ~~is~~ was dissolved from this concentrate ~~with~~ using sulfuric acid in rubber-lined vessels held at 140°F. The leach liquor and pulp ~~are~~ were placed in agitation tanks with granular activated charcoal. The charcoal absorbs practically all the molybdenum, but little else. The loaded charcoal ~~is~~ was separated from the waste slurry by screens. Molybdenum ~~is~~ was stripped from the charcoal by dissolving in an ammonia solution, and the charcoal returned to the absorption circuit and used again. The molybdenum-bearing ammonia solution ~~is~~ was evaporated to produce crystals of ammonium molybdate which ~~are~~ was heated to 1075°F. in a rotary kiln and converted to molybdic oxide. (Amax Journal, vol. 4, no. 4, 1966).

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Processing and Marketing

The plants that convert the raw materials to useful products almost always receive the molybdenum as molybdenite concentrates from mills at the mines. The concentrates contain 50 to 95 percent molybdenite, but 95 percent is considered a standard grade for price quotations. Industry specifications for the concentrates vary; National Stockpile specifications require more than 90 percent molybdenite and less than 0.45 percent copper, less than 0.15 percent lead, less than 0.04 percent phosphorus, and less than 0.15 percent combined tin and arsenic. Other buyers will accept concentrates containing up to twice as much copper and lead. The present (July 1978) ~~(December, 1967)~~ price for concentrates containing 90 percent molybdenite is $1.~~02~~ 72 a pound of contained molybdenum plus the cost of the container (fig. _).

Figure _. Price of molybdenite concentrates (1920-1927 prices are averages of widely varying prices).

Virtually all the molybdenite (MoS_2) concentrates are roasted to molybdic oxide (MoO_3), which in turn is the starting material in producing most other

molybdenum products. Technical grade (roasted concentrate) molybdic oxide in bags presently (~~December, 1967~~ July 1971) sells for $1.~~31~~ 91 a pound of contained molybdenum.

For use in alloys, the molybdic oxide is made into briquettes or converted to ferromolybdenum ($2.~~11~~ 21 a pound in lumps), calcium molybdate, or molybdenum silicide. The molybdic oxide also is reduced to molybdenum metal powder ($~~3.75~~ 4.00 a pound), which is consolidated into useable forms by pressing and sintering the powder, or increasingly, by vacuum melting. Pure molybdic oxide is made from the technical grade oxide by sublimation; this pure material is suitable for chemical and catalytic uses. Schneider (1963, p. 57-66) describes the conversion methods used in American plants.

Present Production and Consumption

The United States consumes 50 percent of the molybdenum used in the world; European countries, the U.S.S.R., and Japan consume much of the rest. By ~~1966~~ 1970, world production of molybdenum had risen to ~~140~~ 160 million pounds. The United States produces 65 percent of this total, other Free World nations 20 percent, and the Communist bloc 15 percent (fig. _).

The Climax mine in Colorado presently supplies 40 percent of the world's and 60 percent of the United States' production. About 20 percent of world production comes from other porphyry-molybdenum deposits, principally Questa, New Mexico, Urad, Colorado, and Endako and Boss Mountain in British Columbia, Canada. Most of the remaining world output is recovered as a by-product from porphyry-copper mines in the United States (Arizona, Utah, New Mexico, and Nevada), the U.S.S.R., Chile, Peru, and Canada. Significant but relatively small amounts of molybdenum also are recovered from vein deposits in Canada, Japan, and Norway, and as a coproduct from tungsten mines in California and the U.S.S.R.

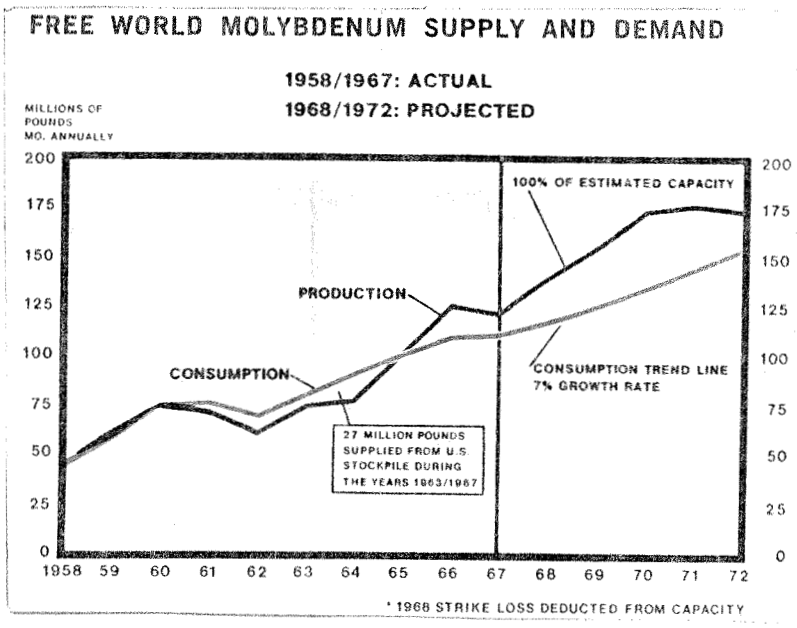

Figure __. Molybdenum supply and demand in the free world (after Kennecott Copper Corp., A report on operations, 1968).

Nevada presently ranks sixth among the states (after Colorado, Arizona, Utah, New Mexico, and California) in molybdenum production. All the State's current production is from open-pit copper mines of the Kennecott Copper Corporation at Ruth near Ely. The Hall deposit near Tonopah will add substantially to the State's output when it is brought into production.

Future Outlook and Resources

Because of its versatility and abundance, there is no doubt that the demand for molybdenum will continue to increase rapidly for many years. United States' needs will continue to rise, but consumption in Europe, the U.S.S.R., and Japan will increase at a proportionately bigger rate. The metal's consumption in alloy steels will remain its major use because of a marked increase in demand for these steels, particularly abroad. Other uses of molybdenum are expected to consume increasing, and proportionately greater, amounts of the metal. The producers, especially American Metal Climax, can be expected to stimulate demand by continued aggressive research.

The many new mines opened in the last few years have changed the picture from one of shortages to one of adequate supplies, and could result in an over supply over the near term. This has led some companies to curtail exploration. However, the continued rapid increase in consumption will soon again outstrip production unless a number of additional new mines are found.

The United States for some time will remain the largest producer and supplier in the world. The Communist bloc, especially Russia, is rapidly expanding exploration and development efforts and, within the next decade, could conceivably rival the United States as a source. Canada, Chile, and Peru will have increasing production and continue to be important suppliers. And molybdenum deposits will be found elsewhere in the world, and other nations could become important producers.

The Climax mine will continue to dominate world production and reserves, but to a decreasing extent; proven reserves ~~are~~ were conservatively estimated at 455 million tons of ore containing more than 2 billion pounds of molybdenum (1962 Annual Report, American Metal Climax, Inc.). Other porphyry-molybdenum deposits have substantial reserves and will be major producers; these include the Urad-Henderson complex ~~mine~~, Colorado, the Questa mine deposit, New Mexico, the Hall property, Nevada, and the Endako and other mines in British Columbia.

By-product recovery of molybdenum from porphyry-copper ores will continue to increase and remain the second most important source of metal. A number of mines are increasing ore production; others are improving molybdenum recovery units; and a number of other deposits are being readied for production. Reserves of molybdenum in this type of deposit are huge. It should be remembered that the rate of production from this type deposit is closely tied to the demand for copper.

Coproduct and by-product recovery of molybdenum from tungsten ore will probably remain a relatively small but significant source of the metal. An important part of future Russian production probably will be from this type of deposit. Large amounts of molybdenum could be recovered as a by-product from many of the tungsten deposits of the western United States; the possibility of exploiting these potentially important reserves has not been given the attention it deserves.

Veins and oxidized lead-zinc deposits are not expected to be important future sources of molybdenum.

An intensive worldwide search is under way for new porphyry-copper and porphyry-molybdenum deposits. The Russians also are actively exploring and developing molybdenum-bearing tungsten deposits, but this type of occurrence is being neglected in other countries. Mass-mining plus recovery of molybdenum (as molybdenite, powellite, and molybdian scheelite), copper, bismuth,

and other by-products could lead to the profitable mining of tungsten-contact deposits in the western United States as well as elsewhere in the world. Substantial tonnages of low-grade tungsten ~~are~~ ore remaining at many of the deposits that are considered to be mined out. The evolution from selective to mass mining took place many years ago in the mining of copper, but only recently in the mining of gold. And there is no reason to suppose that this concept can not be extended to tungsten.

Other ways will be found to increase molybdenum output. There are many potential sources of molybdenum, including bedded uranium deposits and molybdenum-bearing shales. Secondary molybdenum minerals, which currently are being wasted ~~except as chemicals~~, will increasingly be recovered. And improved flotation methods and new techniques such as leaching will be used to recover molybdenum now lost during beneficiation.

Nevada presently is only a small producer of molybdenum; molybdenite is only recovered from one of the four porphyry-copper deposits presently being mined in the State, the other three contain too little molybdenite to make recovery profitable. The State will become a substantial producer when the Hall porphyry-molybdenum mine is opened. And The possibility of finding other minable molybdenum deposits in the State is good; many companies presently are searching for deposits of the porphyry type. The State's potential could be increased substantially if a serious effort were made to exploit the contact-tungsten deposits mentioned above.

GEOLOGY OF MOLYBDENUM

Mineralogy

Molybdenum Minerals (Table ___)

Molybdenite (MoS_2). Molybdenite is the most common molybdenum mineral and presently is the only important source of the metal. One hundred and seven of the 137 molybdenum occurrences in Nevada contain molybdenite. It closely resembles graphite in color (lead-gray), softness, and flaky structure. It occurs widely throughout the world, the western United States, and Nevada, usually as soft, lead-gray tabular hexagonal plates and flakes. Molybdenite is a primary mineral; it is found as an accessory mineral in granitic rocks, in pegmatites and aplites, in quartz veins, in porphyry-copper deposits, in quartz stockworks and disseminations containing no copper, in contact-metasomatic tungsten deposits, and in lead-zinc replacement bodies.

Wulfenite ($PbMoO_4$). Wulfenite is the second most abundant molybdenum mineral. Before World War I, wulfenite was the most important source of molybdenum, but presently little wulfenite is being mined. The mineral is common in the southwestern United States and elsewhere in the world

Table ___. Chemical and Physical Properties of Molybdenum Minerals.

but it is much less widespread than molybdenite. Thirty-five of the 137 molybdenum occurrences in Nevada contain wulfenite. It usually occurs as orange or yellow tabular crystals in the oxidized parts of lead-zinc replacement bodies in limestone.

Powellite ($Ca(Mo,W)O_4$). Powellite, although rare, is a more common molybdenum mineral than is generally supposed. It has never been economically important as a source of molybdenum. Powellite commonly is impure with

TABLE 1. CHEMICAL AND PHYSICAL PROPERTIES OF MOLYBDENUM MINERALS

Name	Composition	% Mo	Usual color	Luster	Hardness (Moh's scale)	Specific gravity	Streak	Crystal system
molybdenite	MoS_2	60	lead-gray	metallic	1	4.7	blue-gray (on paper) greenish (on porcelain)	hexagonal
wulfenite	$PbMoO_4$	26	orange, yellow, gray-white, red, green	resinous to adamantine	3	6.7	white	tetragonal
powellite	$Ca(Mo,W)O_4$	39-48	gray, white, pale yellow, pale brown	pearly to earthy	4	4.2-4.5	white	tetragonal
ferrimolybdite	$Fe_2(MoO_4)_3 \cdot 8H_2O$	40	canary yellow	silky, earthy	1½	3.0-4.5	pale yellow	orthorhombic
ilsemannite	$Mo_3O_8 \cdot nH_2O$?	—	blue-black	earthy	—	—	—	—
jordisite	MoS_2	60	gray-black	earthy	—	—	—	amorphous
chillagite	$3PbWO_4 \cdot PbMoO_4$	12	yellow	vitreous to adamantine	3½	7.5	—	tetragonal
koechlinite	$(BiO)_2(MoO_4)$	15	greenish yellow	—	—	8.3	pale greenish yellow	orthorhombic
lindgrenite	$Cu_3(MoO_4)_2(OH)_2$	36	yellowish green	—	4½	4.3	—	monoclinic
umohoite	$UO_2 \cdot MoO_4 \cdot 2H_2O$	22	black	vitreous	2	4.5	black	—

$MoO_2 \cdot 4MoO_3 \cdot 2 \cdot MoO_3 \cdot SO_3 \cdot 5H_2O$

$Ca(UO_2)_3(MoO_4)_2(OH) \cdot 5H$

up to 10 percent tungsten. It usually occurs as powdery white replacements of molybdenite in tungsten-contact deposits and probably also is present as a primary mineral in some of these same deposits. Powellite is considered to be rare in other types of deposits, probably at least in part because of its inconspicuous appearance which leads it to be easily overlooked. Powellite fluoresces golden yellow; this is the most widely used method of identification. Unfortunately, molybdian scheelite also fluoresces yellow. As a result, in many instances, powellite has come to mean any mineral in the powellite-scheelite series that fluoresces yellow. "Powellite" has been reported from 24 localities in Nevada. The occurrence at Divide, Esmeralda County, is unusual in containing well-formed crystals of powellite.

Ferrimolybdite ($Fe_2(MoO_4)_3 \cdot 8H_2O$). Ferrimolybdite is common in molybdenite-bearing deposits. It has been only a minor source of molybdenum. Ferrimolybdite generally is impure and mixed or associated with limonite. It is an oxidation product of molybdenite and usually occurs as fine, sulfur-yellow needles or earthy aggregates at or within a few feet of the molybdenite from which it was derived. It is the "limonite" of the molybdenum minerals and frequently is mistaken for limonite or jarosite. It has been noted in only a few Nevada deposits, but undoubtedly is present in most of the other occurrences containing molybdenite.

Ilsemannite ($Mo_3O_8 \cdot nH_2O$). Ilsemannite is a dark to pale blue double oxide of molybdenum. Its composition is uncertain and what has been called ilsemannite may actually be several distinct minerals. Most mineralogists have applied the term ilsemannite to any molybdenum compound or mixture that is water-soluble and blue in solution. It reportedly is formed by the oxidation of molybdenite, jordisite, or wulfenite. Because it is highly soluble in water, it generally is found only in arid regions.

Ilsemannite is fairly common in the uranium deposits of the Colorado Plateau. At the Kerr-McGee mill at Ambrosia Lake, New Mexico the molybdenum in the uranium ore is recovered by being precipitated from the leaching fluid as ammonium phosphomolybdate. It is present in 6 of the 137 molybdenum occurrences in Nevada; in 3 of these occurrences the ilsemannite is associated with molybdenite in the other 3 occurrences no other molybdenum minerals were noted.

Jordisite (MoS_2). Jordisite, a powdery black amorphous form of molybdenum sulfide, is a rare mineral, but it is more abundant than was realized. Until recently it has never been utilized as an ore of molybdenum. During the leaching process used to recover uranium, the jordisite also goes into solution, and at the Kerr-McGee mill at Ambrosia Lake, New Mexico, the molybdenum is then recovered as ammonium phosphomolybdate. Jordisite is common in the uranium deposits of New Mexico and Wyoming; it has not been reported in Nevada. Black powdery molybdenum-rich material at Divide, Esmeralda County, may be jordisite but is so impure that it could not be identified positively.

Other molybdenum minerals. There are a number of molybdenum minerals which are rare and have not been utilized as molybdenum ore. None is known to occur in ~~New Mexico~~ Nevada. These rare minerals include chillagite [$3PbWO_4 \cdot PbMoO_4$], koechlinite [$BiO_2 \cdot MoO_4$], lindgrenite [$Cu_3(MoO_4)_2(OH)_2$], belonesite [magnesium molybdate], pateraite [cobalt molybdate], ~~pateraite [cobalt molybdate]~~, eosite [lead molybdate-vanadate], and achrematite [lead chloride-arsenate-vanadate].

Molybdian minerals. Other minerals contain significant amounts of molybdenum. Scheelite commonly contains up to several percent molybdenum in place of part of the tungsten, and a complete series may exist between

scheelite (more tungsten than molybdenum) and powellite (more molybdenum than tungsten). The percentage of molybdenum in scheelite can be readily determined by the color it fluoresces; scheelite containing no molybdenum fluoresces blue-white, with the color changing to pale yellow as the molybdenum content increases (Greenwood, 1943). Although molybdian scheelite has not been utilized except on a small scale as an ore of molybdenum, it is a potentially important source of the metal. Yellow-fluorescing scheelite has been reported from 7 of the 41 scheelite localities in Nevada; what has been identified as "powellite" in many cases also may be molybdian scheelite.

The limonite and jarosite in deposits containing molybdenum usually contain appreciable amounts of the metal. Molybdenum has been produced from this source only at the Climax mine, Colorado.

Manganese-oxide minerals commonly carry appreciable amounts of various metals including molybdenum. No molybdenum has been recovered from this source. There is at least one occurrence in Nevada, and it is quite likely that molybd~~enum~~ian manganese oxides are present elsewhere in the State.

<u>Rhenium in Molybdenite</u>

There are no definite rhenium minerals (rhenium sulfide has been reported, but needs confirmation), and although trace amounts of this rare metal are found in many minerals, it is particularly abundant in molybdenite, which contains up to 0.3 percent. Essentially, all the rhenium now being produced is recovered from flue gas and dust resulting from the roasting of molybdenite concentrates from porphyry-copper deposits. Only a few thousand pounds of rhenium are consumed annually in the United States, but it is estimated that some 20 tons of the metal could be recovered from molybdenite concentrates presently being produced in this country.

The rhenium in molybdenite is of interest not only as the sole important source of the metal but also because the amount of rhenium in molybdenite from different types of deposits varies systematically. Molybdenites from porphyry-copper deposits are rhenium-rich; those from porphyry-molybdenum deposits, copper-barren quartz veins, and tungsten-contact (skarn) deposits are rhenium-poor. This systematic variation was first reported by Zhirov and Ivanova (1959) and has since been confirmed by others.

A more extensive study by Schilling and Giles (1972) on over 200 samples from 40 different deposits throughout the world, showed that the rhenium content of molybdenite in 90 samples from 16 different porphyry-copper deposits contained 200-3000 (mean 660) ppm Re, compared to 20-130 (mean 47) ppm Re in 39 samples from 6 porphyry-molybdenum and quartz-vein deposits. Molybdenites from greisen, pegmatite (e.g. Lacorne, Canada), and contact-tungsten (e.g. Pine Creek, California) deposits show the same range of rhenium content as the porphyry-molybdenum deposits and quartz veins; the lowest (< 1 ppm) values were from molybdenites related to syenitic intrusives (Renfrew, Canada). Variations within the Bingham porphyry-copper deposit are zonal, the mean and range of rhenium in molybdenite decreasing inward and with depth in the intrusive-mineral complex. In the porphyry-molybdenum orebodies at Questa and B. C. Molybdenum, successively younger molybdenites in the multistage paragenetic sequence are progressively enriched in rhenium. The data from this study imply that temperature of formation affects the amount of rhenium in the molybdenite: "higher" temperatures of early-separated fluids (in close proximity to, and derived from, strongly differentiated felsic magma) that form porphyry-molybdenum and contact-tungsten deposits inhibits concentration of rhenium

in molybdenite; the lower temperatures attributed to porphyry-copper deposits favors the concentration of rhenium. Molybdenite polytypism and/or concentration of rhenium in ore-fluid copper-bearing complexes may also be important factors.

Rhenium has been extracted by the Kennecott Copper Corporation from molybdenite concentrates produced at its porphyry-copper open-pit mines in the western United States, including Ely (Robinson district), Nevada. Molybdenite (16 samples) from the Ely porphyry-copper deposits contained 1420 to 2980 ppm rhenium (Giles and Schilling, 1972) making it the rhenium-richest molybdenite reported. Molybdenite from the Getchell, Tempiute, and Linka contact-tungsten deposits in Nevada contained 26-34, 44, and 38 ppm rhenium respectively (Giles and Schilling, 1972).

Types of Deposits

Molybdenum deposits can be classified in numerous ways --- by mineralogy, associated metals, wall rock, size, shape, grade, minability, etc. The following grouping takes into account all these factors, providing categories that are both economically and geologically significant.

Porphyry-Copper Deposits

One of the two important sources of molybdenum is the porphyry-copper deposits of the United States, Canada, Chile, Peru, and the U.S.S.R. These deposits presently supply somewhat less than half the total world output as a by-product of copper mining. The Bingham Canyon (Utah) mine, the largest copper mine in the world, has produced 8 million tons of copper and half a billion pounds of molybdenite (Cook, 1961). Other porphyry-copper mines that have produced molybdenum are the Bethlehem mine, British Columbia, Canada; the Bagdad, Esperanza, Miami, Mineral Park, Mission, Morenci, San Manuel, Sierrita, and Silver Bell mines, Arizona; Santa Rita, New Mexico; Cananea, Mexico; Toquepala, Peru; Braden, Chuquicamata, El Salvador, and Portrerillos, Chile; and the Agarak, Kodgharan, and Kounrad mines, the U.S.S.R. These mines use mass-mining methods, open-pitting or block-caving.

The Kennecott Copper Corp. mines in the Robinson mining district near Ely, White Pine County, are the only Nevada mines of this type that have produced molybdenum. Surprisingly, molybdenite is rare in the other Nevada porphyry-copper mines --- Yerington (Weed Heights), Copper Basin, and Copper Canyon --- so no molybdenite has been recovered. The deposits in the Gilbert and Crow Spring mining districts, Esmeralda County; the Molly and Elder Creek deposits, Humboldt County; the Copper Canyon deposit, Lander County; the McCoy prospect, Lyon County; the Copper Mountain, New Boston, Pilot, and Lylander deposits, and the deposit in the Santa Fe mining district, Mineral County; the deposit in the Spanish Belt mining district, Nye County; and the

Oddie Tunnel and Monte Cristo deposits, White Pine County, all are occurrences of this type (pl. 1).

In these deposits, chalcopyrite and other primary copper minerals, pyrite, and, in most instances, molybdenite occur as disseminated grains and in stockworks of crisscrossing quartz veinlets usually in hydrothermally altered, acid-to-intermediate intrusive bodies and the intruded country rock. The deposits are structurally rather than stratigraphically controlled, the degree of fracturing being the important factor. Oxidation generally has taken place at the surface, and much of the copper has migrated to a zone of enrichment, while the molybdenum usually has remained in place after being converted to an oxide. The deposits presently being exploited contain from 0.4 to 2.0 percent copper and 0.1 to less than 0.01 percent molybdenum. Much has been written about the geology of porphyry-copper deposits, and their exploration; the reader is referred to Parsons (1933 and 1957), Jerome (1963), Titley & Hicks (1966), Lowell & Guilbert (1970), and Rose (1970).

Porphyry-Molybdenum Deposits

The porphyry-molybdenum deposits differ from the porphyry-copper deposits principally in containing little or no copper and from the quartz veins in consisting of stockworks and disseminations rather than distinct, throughgoing veins.

One mine of this type, the Climax in Colorado, has produced more than a billion pounds of molybdenite, more than half the total world output of molybdenum (Wallace et al., 1960). The Climax mine, which is the largest underground mine in the United States with a daily production of 45,000 tons of ore, presently exploits ore containing 0.4 percent molybdenite. The Urad-Henderson mine complex, Colorado, the Questa mine, New Mexico, and the Endako mine in British Columbia, Canada, all are of this type. Together, this group is the main source of molybdenum, although rivalled by the porphyry-copper deposits. Twelve of the 135 molybdenum occurrences in Nevada are of this

type (see plate 1); at least one of these, the Hall property, is destined to become a large, open-pit mine.

The porphyry-molybdenum deposits contain molybdenite in quartz stockwork-veinlets (commonly with pyrite), and/or as paint-thin films along fractures, and/or as disseminated flakes in the wallrock. Base-metal sulfide minerals are rare. Like the porphyry-copper deposits, the porphyry-molybdenum deposits are structurally rather than stratigraphically controlled, and are in hydrothermally altered, acid-to-intermediate intrusive bodies and the intruded country rock. In contrast to the copper minerals, when molybdenite is oxidized it usually remains in place thus there is no enriched zone in most porphyry-molybdenum ore bodies and the grade of the oxidized ore in a general way is the same as the primary (unoxidized) ore. (Molybdenum can be leached from the uppermost layers of soil by the intenser weathering processes that exist at the surface, thus one should not assume that surface samples will always indicate the grade of the molybdenum mineralization immediately below.)

Although there are many similarities between porphyry-copper and porphyry-molybdenum deposits, in detail they differ markedly. Unfortunately no detailed in-depth studies have been published on the characteristics of porphyry-molybdenum deposits; the reader must ferret out and synthesize this information mainly from the numerous descriptions of individual deposits that abound in the literature. The following publications are especially useful: Lowell & Guilbert, 1970 (general); Wallace and others, 1960 and 1968 (Climax); MacKenzie, 1970 (Urad-Henderson); Brown, 1969 (Endako, B.C. Moly, Boss Mtn., British Columbia)

One interesting feature is the multiple-stage intrusion and multi-stages (and multi-shelled) mineralization characteristic of many porphyry-molybdenum deposits such as Climax (Wallace and others, 1960) and Urad-Henderson (MacKenzie, 1970). The mineralization at other porphyry-molybdenum

deposits such as Questa also is multi-stages; whether these deposits also have multiple shells of mineralization often is obscured because the deposit is deeply eroded, or conversely because deep drilling is lacking.

Not only did the emplacement of the intrusive rocks associated with molybdenum-porphyry deposits take place as multiple pulses, but intrusion was a quite active process --- ring dikes, radial dikes, and breccia pipes are common associated features. Breccia pipes are especially diagnostic features of multiple-stage molybdenum-porphyry deposits. (Under the term breccia pipe I am including intrusive breccias, volcanic necks, plugs, rubble pipes, diatremes, intrusive columns, etc.). Breccia pipes are associated with most, possibly all, porphyry-type deposits; the Urad-Henderson deposits are a classical example of the close association of a breccia pipe with molybdenum mineralization (MacKenzie, 1970). Any magma in the earth's upper crust can produce a breccia pipe as the consequence of normal cooling and crystallization. Residual fluids and volatiles will tend to concentrate in the upper high spots of the magma body as it begins to cool. The roof rocks above such a cupola will collapse and be fragmented as the magma continues to crystallize and shrink, allowing a column of intrusive breccia to work its way upward from the cupola, or gas in the cupola will "eat" its way upward by a process of fluidization in which rock fragments commonly have been displaced both up and down in breccia pipes. The intrusion of igneous material may precede, accompany, or follow the process of fluidization; the intrusive rock usually has been called "quartz porphyry," "felsite," "rhyolite," or "aplite." Several surges of pipe formation usually take place, and succeeding pipes often follow the path of least resistance and almost or completely destroy the earlier pipes and any mineralization. Not all pipes have vented to the surface as volcanos, some formed extrusive-intrusive domes, others have leaked to the surface along fractures or as rubble dikes, while others appear to have been almost completely contained. Last-stage andesitic dikes commonly are intruded as the concluding

Figure __. Diagrammatic model of a breccia pipe's formation.

events in the igneous cycle. (Bryner, 1961; Emmons, 1938; Eyrich, 1971; Johnston & Lowell, 1961; Locke, 1926; Perry, 1961; Reynolds, 1954).

Each intrusive surge commonly is accompanied by mineralization, which usually occurs as a last stage of each pulse, but also may accompany or even precede the formation of a pipe, or be completely absent.

no ¶ Each shell of molybdenum mineralization usually is draped over the top of the cupola and in the roots of the breccia pipe, although varying conditions of deposition can result in the shell being displaced upward into the pipe or lowered into the underlying porphyry body.

The alteration is similar in porphyry-copper and porphyry-molybdenum deposits, but there are certain distinct differences. In a general way argillization is most commonly closely-spacially associated with copper mineralization, and thus, usually is more pervasive and intense in the copper-richer portions of the porphyry-copper deposits and considerably rarer in the porphyry-molybdenum deposits as well as in the pyrite-molybdenite-richer, copper-poorer portions of the porphyry-copper deposits. In contrast, the porphyry-molybdenum deposits generally are characterised by intense silica flooding and/or the presence of numerous, criss-crossing quartz veinlets; K-felspathization also usually is more common, although apparently less diagnostic. Silica flooding, quartz veinlets, and K-felspathization also usually are more common in the molybdenum-richer portions of porphyry-copper deposits. Sericite is common in both associations. The above should be considered only as a gross generalization; individual deposits should not be expected to closely fit this model.

In the porphyry-molybdenum deposits a shell of weak but distinct tungsten mineralization usually is present above each shell of molybdenite mineraliaztion.

A shell of pyrite usually occurs between the tungsten and molybdenum shells and overlaps downward with the molybdenum mineralization. Fluorite also is common, both in the veinlets and dessiminated through the deposit, any accompanying breccia pipe, and to a lesser extent in the country rock. Tin, beryllium, lead, and zinc also often are present in anomalously large amounts. The trace elements, like the alteration, usually occur as shells concentric to each shell of molybdenum mineral. The order of zoning is not always the same, however the lead-zinc shell is nearly always outward and upward from the close-in tungsten shell.

Granitic intrusives of any age can be expected to have associated porphyry-molybdenum deposits --- no acid to intermediate intrusives should be ignored in the search for deposits of this type, solely because they are of the "wrong" age. However, magmas from certain regions (and also sometimes of a particular age) appear to have been more molybdenum-rich (or copper-rich) than average --- if this is indeed true, intrusives of a given age in a given area could on the average be expected to contain ~~rather~~ richer and/or larger deposits. In a general way, uplift and subsequent erosion will have eroded older intrusive bodies so deeply that any associated porphyry-molybdenum deposits will have been destroyed; intermediate age intrusive will have their associated deposits partially eroded; while young intrusives will still remain deeply buried --- thus, if uplift and erosion has been somewhat uniform over a given area, intrusives of a given age (on the average) may have more economic potential as targets for exploration than those of any other age. Both factors (molybdenum-richer source rocks, and optimum erosion) explain why Miocene intrusives in Colorado and New Mexico, are particularly favorable targets (Climax, Urad-Henderson, and Questa all are associated with Miocene intrusives). In Nevada, Cretaceous intrusives on the average seem to have been eroded until the associated molybdenum mineralization is exposed, while the molybdenum

mineralization with younger intrusives (and the intrusives themselves) remain buried and their location only surmised indirectly.

Most ore deposits found in the past actually have had mineralization exposed at the surface. In recent years, more and more shallow deposits have been located under their surface alteration and geochemical haloes, or by their geophysical characteristics. Many geologists have said that future exploration must be directed towards locating covered deposits --- those deposits that are hidden under younger rocks, and have no surface expression. My plea is to not ignore an intermediate class of deposit that are ~~deeply~~ buried but still have an indirect surface expression --- that felsitic breccia pipes, rhyolite domes, rhyolitic volcanic centers, ring dikes, epithermal ore deposits, etc., should be considered as possible guides to ore deposits at deep yet mineable depths. This is particularly true for porphyry-molybdenum deposits --- the discovery of the huge Henderson orebody bears witness to this potential.

Quartz Veins

Molybdenite commonly occurs in distinct, throughgoing quartz veins with or without other sulfide minerals. Pyrite and chalcopyrite usually are associated with the molybdenite, and many veins also contain fluorite, galena, and/or sphalerite. In Asia, tungsten (scheelite and wolframite), tin (cassiterite), and molybdenite occur together in quartz veins; this association is rarer elsewhere in the world. In many instances, acid-to-intermediate intrusive bodies are associated with the molybdenite-bearing quartz veins. The veins show no preference as to type of wall rock but are controlled by the availability of open space. The wall rock next to many of the veins is hydrothermally altered. This type deposit differs from the porphyry deposits ~~only~~ mainly in having the mineralization concentrated in a few through-going structures.

The largest mine of this type, the Questa molybdenum mine, Taos County, New Mexico, produced more than 20 million pounds of molybdenite from quartz veins that contained 1 to more than 20 percent MoS_2 but no other values (Schilling, 1956). Although many other mines throughout the world have produced molybdenite from quartz veins, this type of deposit is no longer a major source of molybdenum. Selective underground methods are used to mine these deposits.

Some 44 of the 135 molybdenum occurrences in Nevada are of this type; they are not concentrated in one area but are scattered throughout the State. Most (35) of these occurrences consist of only a few flakes of molybdenum; all are small. Only the Southam mine is reported to have had any production. The powellite-ferrimolybdite occurrence at Divide, south of Tonopah, is considered to be an oxidized example of this type deposit, as are two localities where ilsemannite is the only molybdenum mineral present.

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Contact-Tungsten Deposits

Molybdenite and powellite commonly occur in tungsten (scheelite)-bearing contact-metasomatic deposits (tactites or skarns) developed in lime-rich rocks adjacent to granitic intrusive bodies. And the scheelite in some of these deposits contains up to several percent molybdenum in place of part of the tungsten. The molybdenite generally is disseminated through the skarn as scattered flakes or in quartz veinlets. Although the deposition of the scheelite and skarn is mainly stratigraphically controlled, the deposition of the molybdenite is structurally controlled by fractures and faults and is superimposed on the tungsten mineralization and skarn. (In a way, contact deposits are actually porphyry deposits formed in a carbonate host rock instead of porphyry.) Pyrite, chalcopyrite, sphalerite, and bismuthmite commonly are associated with the molybdenite.

In most instances, the molybdenum minerals are present in such small amounts that they can be recovered only as by-products. The Pine Creek mine, California (Bateman, 1956), Tyrny-Auz mine, the U.S.S.R., and Azeguar deposits

Algeria, have been the only important producers of this type. Both selective and mass-mining methods have been used to exploit these deposits. As has been pointed out elsewhere in this report, the possibility of exploiting this type deposit for molybdenum (as a byproduct) has not been given the attention it deserves.

Thirty-nine of the 135 molybdenum occurrences in Nevada are of this type (pl. 1). Molybdenum-bearing tungsten-contact deposits are not concentrated in one area but are scattered over the same region in which the other molybdenum and tungsten deposits occur (pl. 1). Seventeen of the deposits contain molybdenite, and powellite and/or molybdian scheelite; twelve contain only molybdenite; ten contain only powellite and/or molybdian scheelite. Only the Getchell Mine, Humboldt County, has produced molybdenum.

Oxidized Lead-Zinc Deposits

Wulfenite is present in the oxidized parts of some lead-zinc veins and replacement bodies. These deposits usually are in limestones and are stratigraphically controlled and structurally localized. Before World War I, this was the most important source of molybdenum, but at present, little or no molybdenum is recovered from this type of deposit. Production of wulfenite from any mine has been relatively small; the Mammoth mine, Arizona, which has been by far the largest of this type, has produced less than a million pounds of molybdenum (Peterson, 1938). These deposits generally have been mined by selective underground methods.

The ores of these deposits are complex. Pyrite, chalcopyrite, barite, and vanadium minerals are present in many of the deposits. Sulfide (primary), carbonate (secondary), oxide (secondary), and mixed ores of lead, zinc, copper, gold, and silver have been mined together or in various combinations. Usually, the wulfenite has been recovered as a by-product or coproduct.

The wulfenite ($PbMoO_4$) is believed to have formed either (1) by the interaction of oxidized lead (galena) deposits and molybdenum-bearing thermal waters that derived the molybdenum from wall rocks or hydrothermal sources or (2) by the interaction of the oxidation products of galena with those of molybdenite or molybdenum-bearing minerals. The first theory was proposed because of the apparent rarity of molybdenite and other molybdenum-bearing minerals in deposits containing wulfenite. However, molybdenite is present in many more lead-zinc deposits than was once realized. Its absence in other deposits probably is due to the completeness with which molybdenite, like sphalerite, is destroyed by oxidation processes. Many lead-zinc deposits in which wulfenite is found either are entirely in or have not been explored below the zone of oxidation, and they contain no sphalerite or molybdenite, though some of the galena remains unoxidized. At six out of the 28 wulfenite occurrences in Nevada, molybdenite is known to occur in the unoxidized parts of the same deposit. Work by Newhouse (1934) has shown that pyrite, sphalerite, and galena from lead-zinc deposits commonly contain molybdenum (and vanadium), providing another potential source. It therefore seems likely that wulfenite (and its companion vanadinite) is formed entirely by the oxidation of the lead-zinc deposit in which it occurs.

Twenty-eight of the 135 molybdenum occurrences in Nevada are of the oxidized lead-zinc type (pl. 2). Wulfenite has been produced from the Shenandoah mine in the Goodsprings district, Clark County.

Pegmatites and Aplites

Molybdenite is present in some aplite dikes and pegmatite bodies as disseminated flakes and pods. Although some have been mined, this type of deposit has never been a major source of molybdenum. None of the molybdenum occurrences in Nevada are considered to be of this type. Many aplites, pegmatites, and quartz veins are in or near large granitic bodies and

and apparently are end-stage differentiates from the bodies. The pegmatites and aplites usually are genetically related to the quartz veins and in some cases can be seen to grade laterally into the veins.

Bedded Uranium Deposits

Jordisite and ilsemannite occur in many of the uranium deposits of the Colorado Plateau. Both minerals are widespread and relatively abundant in many of the deposits of the Grants uranium belt (Society of Economic Geologists, 1963).

This type differs markedly from the other types of molybdenum deposits that have been described. The other types of deposits are closely related to one another, belong to overlapping categories that are intergradational, and are simply variations of one class of deposit. They differ from the uranium deposits in being associated spatially and genetically with acid-to-intermediate intrusives; in containing molybdenite rather than jordisite; in containing significant amounts of copper, lead, zinc, and tungsten but no uranium; and in being veins and irregular bodies rather than bedded deposits. The origin of these uranium deposits remains uncertain.

At the Kerr-McGee mill, Ambrosia Lake, New Mexico, molybdenum is recovered from bedded uranium ores from the Ambrosia Lake, and Wyoming lignite, ores, in the form of ammonium phosphomolybdate. ~~The deposits of the Grants uranium belt are a potentially important source~~.

Anamolously-high molybdenum values have been reported from samples taken from the lake-bed uranium deposits near Tonopah (Larry Garside, personal communication); little is known about its possible occurrence in other Nevada uranium deposits.

Black Shales

Black shales are a potential source of many metals including molybdenum. Black shales are present in Nevada, but no data is available on their

molybdenum content. Molybdenum reportedly is present in the Gibellini vanadium deposit, southern Eureka County. This potential resource deserves more study in Nevada.

Manganese-Oxide Deposits

Many manganese-oxide deposits contain significant amounts of lead and zinc. Millions of pounds of lead and zinc were recovered as a by-product of manganese-oxide mining at the Three Kids mine, near Las Vegas, Nevada. Considerable tungsten has been recovered from a blanket of manganese-oxides at Golconda, Nevada, and tungsten is known to occur in the manganese-oxide deposits at Sodaville, Nevada. Molybdenum and other metals are known to be present in the Socorro, New Mexico, manganese deposits (personal communication, Max Willard), and at the Gibellini manganese mine, Eureka County, Nevada, where samples of manganese oxide contain more than 1/10% Mo. Obviously this potential source of molybdenum also deserves more study.

NEVADA MOLYBDENUM OCCURRENCES

The molybdenum deposits and mineral localities in Nevada, grouped geographically, are described in this section. The coverage is not exhaustive but summarizes our present knowledge of each occurrence. Plate 1 shows the location of the various occurrences.

CHURCHILL COUNTY

Chalk Mountain

The Chalk Mountain mining district is on Chalk Mountain (T. 17 N., R. 34 E.), an isolated, conspicuously-white hill in the northeast corner of Fairview Valley near the south end of the Clan Alpine Range. ~~Extensive~~ underground workings extend~~ing~~ to a depth of 500 feet ~~were made on the east slope of the mountain while mining lead-silver ore from~~ the main vein system in the district (Schrader, 1947). Smaller prospects on the west slope of the mountain explore contact deposits.

Gray-white, medium- to thick-bedded dolomitic, Mesozoic (?) limestone crops out over much of the southern two-thirds of Chalk Mountain. The

Figure ___. Generalized geologic map of the Chalk Mountain mining district.

limestone has been folded into an anticline along the longitudinal (north-south) axis of the mountain. The north third of the mountain is covered with rhyolite and some andesite Tertiary volcanic rocks; andesite also crops out at the southernmost end of the mountain.

A stock of medium-grained porphyritic biotite-hornblende granodiorite intrudes the limestone, and is exposed on the west slope of the mountain. Dikes of gray diorite and white aplite cut both the granodiorite and limestone, and appear to be late stage differentiates from the granodiorite magma.

From the 1860's to 1921, the district sporatically produced small amounts of high-grade lead-silver ore. In 1921, more extensive deposits were found. Several hundred thousand dollars worth of lead-silver ore was produced from 1925 through 1927, mainly from the mine of the Chalk Mountain Silver-Lead Mines Co. which is on the east slope of the mountain.

A

Major north-trending fault zones occur along the east and west edges of the mountain; east-west cross-faults are present about a mile south of the north end, and at the south end of the mountain. Movement occurred along both north-south fault zones during the earthquakes of December 16, 1954, the mountain being uplifted relative to the surrounding area. The dolomite limestone has been extensively shattered and marmarized.

Tungsten Contact Deposits.

The limestone in contact with the granodiorite has been contact-metasomatized, forming a skarn zone up to several hundred feet wide. The skarn contains a variety of contact minerals. Epidote is common and widespread, and locally forms large bodies. Bodies consisting of magnetite, hematite, chlorite, and some pyrite and chalcopyrite also are common. Scheelite and powellite also are present locally in the skarn.

Lead-Silver Veins.

Veins and replacement bodies of lead-silver mineralization occur along faults, fractures, and bedding planes in and adjacent to the north-south fault zone on the east slope of Chalk Mountain; a few similar occurrences are associated with the other faults. The mineralization commonly is some distance from the granodiorite intrusive and contact-metasomatized zone. The ore deposits are mostly oxidized and consist of limestone fragments, quartz, calcite, garnet, epidote, cerussite, anglesite, wulfenite, argentiferous galena, cerargyrite, plumbojarosite, copper carbonates, "limonite", and vanadinite. The unoxidized portions of the deposits contain galena, pyrite, molybdenite, and chalcopyrite.

Nevada Wonder Mine

The Nevada Wonder (Wonder) mine is in Sec. 4 (?) and 9 (?), T. 18 N., R. 35 E., 1/2-mile north of the ghost town of Wonder on the west slope of the Clan Alpine Mountains about six miles north-northeast of Chalk Mountain (see Army Map Service, Millett topographic quadrangle map). The veins of the Wonder district were discovered in 1906. Although there were a number of silver-gold mines in the district only the Nevada Wonder was an important producer. From 1911 to 1919 when the mine closed, it produced over 390,000 tons of ore averaging 18 ounces of silver and 0.25 ounces of gold per ton. There are over 66,000 feet of workings extending to a depth of more than 2,000 feet and horizontally for 3,400 feet (Schrader, 1947).

The vein system of the Nevada Wonder mine has a lineal extent of 1 1/4 miles, and consists of 1 to 4 parallel veins striking N. 25° W. and dipping 75° NE. There are over 40 other, less-productive veins in the district. Nearly all are roughly parallel, trend northwest, and dip steeply. They are along fractures and faults in the 2,000-foot-thick "Wonder" rhyolite, and to a

Figure . Generalized geologic map of the Wonder mining district.

minor extent in other, underlying Tertiary volcanic rocks.

The veins are typically epithermal in character. They vary from less than a foot to over 10 feet in thickness, and consist principally of quartz, and lesser adularia, gouge, and wallrock fragments. Fluorite is locally abundant. In places, the veins are fairly well banded. The gold and silver values are chiefly in the quartz-adularia vein material, but also are present in the gouge and wall rock.

Pyrite, chalcopyrite, argentite, and minor galena and sphalerite occur in the unoxidized portions of the vein; the gold values are associated with the argentite. The veins have been deeply oxidized, oxidation in the Nevada Wonder mine extending quite uniformly to a depth of 1,300 feet. Copper, lead,

and zinc minerals are almost completely absent in the oxidized zone. The silver occurs as cerargyrite, stephanite, embolite, iodobromite, and iodyrite; the gold is present as native gold. Wulfenite occurred from the 300- to 1,300-foot level in the Extension ore shoot which is in the oxidized portion of the vein. A little molybdenite also is present in the veins (Schrader, 1947); the writer was able to find only one specimen --- a few flakes in quartz.

Scott Prospect

Schrader (1947, p. 330) mentions that molybdenite occurs with gold-bearing mineralization at the Scott prospect which is 4 miles north of the Byer Ranch at Granite Point on the eastern foot of the Clan Alpine Mountains (Sec. 21 ?, T. 21 N., R. 38 E.) (see Army Map Service, Millett topographic quadrangle map). Some gold ore has been mined. The mineralization is along a contact of a "granite" body with shale of the Triassic (?) "Star Peak" formation. This occurrence could not be located in the field.

Sand Springs Range

Scheelite and minor powellite occur in small bodies of skarn in limestone in contact with the large cretaceous granodiorite - quartz monzonite pluton, exposed in the Sand Springs Range. The contact tungsten deposits are along the north and southwest borders of the pluton. Tungsten production has been small, the ore nearly all being low grade. (Nevada Bureau of Mines, 1964, p. 34).

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Midnight Mine

The Midnight (Scheelite-Midnight, Bell Flat) mine is in Sec. 6, T. 14 N., R. 34 ~~er~~ E., on the east slope of Slate Mountain. Scheelite and "powellite" occur in three, small, widely-seperate lenses of tactite in calcareous schist near dikes and sills of granite and aplite. A small amount of tungsten ore has been produced from several small open cuts.

GOODSPRINGS ~~CLUSTER~~ MINING DISTRICT, CLARK COUNTY

The Goodsprings (Yellow Pine, Potosi) mining district has produced a great variety of metals including molybdenum. The numerous mines in the district, many of which have extensive workings, are scattered throughout the southern third of the Spring Mountains in Ts. 23, 24, and 25 S., Rs. 57 and 58 E. (see U. S. Geological Survey, Goodsprings 1:62,500 topographic map) in southwestern Clark County.

History. The deposits in the district were first worked in 1856, when some lead ore was mined and smelted. Little work was done until 1891. From 1891 to 1944, production was almost continuous. Since 1944, there has been only minor production. Over a half million tons of ore worth more than 25 million dollars have been mined.

Many types of ore have been mined including: (1) zine; (2) lead-zinc; (3) lead; (4) copper; (5) siliceous gold-silver; (6) molybdenum; (7) vanadium; (8) nickel-cobalt; (9) gold-platinum-palladium; and (10) uranium. The lead zinc-lead, and zinc ores contained important silver values. The nickel-cobalt ore actually is a variant of the copper-ore type; the vanadium ore is a variant of the lead-zinc ore. Large amounts of zinc, lead, silver, copper, and gold (in order of descending value) were produced; only small amounts of the other metals were recovered.

Geology. The geology of the district has been described in detail by Hewitt (1931) and Albritton, and others (1954).

A 13,000-foot sequence of sedimentary rocks crops out in the district. The lower half of the sequence is Paleozoic limestone and dolomite; the upper half is largely shale, sandstone, and conglomerate of Permian, Triassic, and Jurassic (?) ages. Tertiary volcanic rocks and Quaternary sediments locally cover the older rocks. Dikes and sills of "granite porphyry" are common in the central part of the district. Quartz is absent in many of these dikes and sills, and these should be classed as syenite porphyry.

The district has a complex structural pattern which includes folds, thrusts, tears, and rifts. The rocks were first folded to varying degrees depending on their massiveness. Thrusting began toward the end of the period of folding. Four major and many minor thrust faults occur in the district, and generally dip west. The "granite porphyry" was intruded near the end of the epoch of thrusting. After the thrusting, a few normal faults were formed and later mineralized. Later other normal faults were formed which are younger than the ore deposits but older than the middle Tertiary volcanics. Conspicuous breccia zones mark the traces of the major faults. It is interesting to note that the offset of one high-angle fault by another is extremely rare in the district, and that curvatures along many of these faults are unusually great, both in dip and along the strike.

Lead-Zinc Deposits. The lead-zinc ore bodies are dolomite and limestone replacements which, except for rare exceptions, are in the 700-foot-thick Mississippian Monte Cristo Limestone. Where the bedding is flat, the bodies commonly are tabular and parallel the bedding. Where the bedding is inclined, the bodies are irregular pipes that in a few cases follow fractures, but more commonly parallel or cut the bedding at slight angles yet are not parallel to one another.

The lead-zinc mines not only are confined to a narrow stratigraphic zone, but are mostly located where faults (breccia zones) and fractures cut the favorable zone. Because of its massive nature the Monte Cristo Limestone has been more intensely brecciated than other units, and thus provides the most favorable site for ore deposition. However, there are many more conspicuous high-angle faults in the district that are barren than there are faults that are associated with ore. Furthermore, within a fault zone the "master" faults which have the greatest displacement and extent, commonly are barren, whereas subsidiary shears along the same fault zone are mineralized.

The primary minerals were mainly quartz, galena, and sphalerite. Nearly all the sphalerite has been oxidized to hydrozincite, calamine, and some smithsonite. Pods of galena remain in the ore but commonly has been altered to cerussite and lesser anglesite. Chalcopyrite originally was present in a few deposits, but has been largely altered to malachite, chrysocolla, and azurite. The secondary vanadium minerals, cuprodesoloizite, descloizite, and vanadinite are uncommon but widespread. Numerous other minerals occur in smaller amounts.

Oxidation extends below the deepest workings. Galena remnants commonly are scattered through oxidized lead-zinc ore indicating that little migration took place during oxidation.

Molybdenum Occurrences. Wulfenite has been observed in the Shenandoah, Milford, Hoosier, Mobile, Hermosa, Pilgram, Ruth, Smithsonite, Whale, and

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Figure . Generalized geologic map of the Goodsprings mining district showing mines and wulfenite occurrences.

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other mines in the district. All the occurrences, except that of the Milford mine, are clustered in the central part of the district. The wulfenite generally occurs as square tabular, orange to wax-brown crystals lining drusy cavities in small irregular concentrations associated with lead-zinc ore. Like the vanadates, with which it is commonly associated, the wulfenite is one of the latest minerals to be formed.

Shenandoah Mine

Although wulfenite has been found in a number of mines in the district, only at the Shenandoah have efforts been made to mine the wulfenite. The Shenandoah mine is in the north-central part of Sec. 35, T. 24 S., R. 57 E., near the crest of a steep-sided ridge on the west edge of the Spring Mountains; the Shenandoah mill is 2 miles to the southwest, along the Sandy-Goodsprings road at a point one mile east of Sandy.

The mine is developed by several adits and lateral workings totaling 2,500 feet. An aerial gravity-operated tramway 1,650 feet long connected the mine with loading bins on the floor of the gulch. The mine equipment and tramway have been dismantled. In contrast, the mill is intact, and still contains much of the equipment used to concentrate the molybdenum ore.

The property was first located in 1883. For many years lead-zinc ore was mined intermittently on a small scale. In 1935 and 1936, the California Molybdenum Corp., a subsidiary of Climax Molybdenum Corp., took an option on the mine and mill. Some development work was done, and the crude ore that resulted was screened, and the wulfenite in the fines concentrated by flotation at the Shenandoah mill which had been rebuilt to handle the molybdenum ore. Fifty tons of ore could be treated per day. Concentrates containing an estimated 40,000 pounds of molybdenum were produced. Hewitt (1936, p. 89) states that, reportedly, the fines represented about 40 percent of the crude ore, and that 1 ton of concentrates containing 20 percent molybdenum was produced from each 20 tons of fines. Vanderburg (1937, p. 48) adds that: "Judging from the tailings pile at the mill, about 5,000 tons of wulfenite ore were treated . . ." The option was dropped in November 1936.

The wulfenite occurred with cerussite, galena, smithsonite, and hydrozincite in lenses in a breccia zone crosscutting massive, cherty, dolomitized Monte Cristo Limestone striking N. 40° W. and dipping 20° SW. The wulfenite ore was mined from an area 130 feet long, 10 to 30 feet high, and 160 feet wide.

Smithsonite Mine

Wulfenite has been observed at the Smithsonite mine which is some 1,000 feet east-northeast of the Shenandoah mine in the SW corner of Sec. 25 and the SE corner of Sec. 26, T. 24 S., R. 57 E. This mine consists of a 55-foot shaft, 210 feet of drifts, and 2 stopes from which some lead, zinc, and copper have been mined. The ore was galena, cerussite, calamine, and some

chrysocolla, malachite, and aurichalcite and occurred in the brecciated Bullion Dolomite member of the Monte Cristo Limestone.

Mobile Mine

Considerable wulfenite was found in the Mobile mine which is some 1,000 feet east-southeast of the Shenandoah mine and 500 feet south of the Smithsonite mine. Wulfenite occurred in two places as flat, waxey-yellow crystals, many of which are entirely covered by small perfect crystals of calamine. Some zinc, lead, and copper was mined from a brecciated zone along a bedding-plane fault in the Anchor Limestone member of the Monte Cristo Limestone. The ore consisted mainly of hydrozincite, lesser galena and its oxidation products, calamine, and scattered cuprodescloizite.

Whale Mine

The whale mine is in the NW 1/4 of Sec. 1, T. 25 S., R. 57 E., about 1 1/2 miles southeast of the Shenandoah, Smithsonite, and Mobile mines. A number of shallow shafts, short adits, and short drifts were made while mining and exploring for zinc and lead. In the eastern group of workings, small veins containing cuprodescloizite, and locally a little galena, calamine, and wulfenite, are sporadically distributed in dolomitized limestone.

Pilgrim Mine

The Pilgrim mine is in the southcentral part of Sec. 8, T. 24 S., R. 58 E. on the eastern flank of the Spring Mountains. The workings consist of an inclined shaft with several stopes and three levels totaling several hundred feet made while mining lead-zinc ore. Cerussite, galena, hydrozincite, calamine, wulfenite, and pyromorphite occur sporadically along irregular folds in the bedding planes of dolomitized thin-bedded limestone of the Bird Spring member of the Monte Cristo Limestone. The irregular folding and jointing apparently was caused by the Potosi thrust fault which underlies the mine area.

Ruth Mine

The Ruth mine is in NE 1/4 Sec. 29, T. 24 S., R. 58 E., about 2 miles south of the Pilgrim mine. The Yellow Pine mine, the largest lead-zinc producer in the district, is 1 mile to the northwest. An adit with several hundred feet of workings, a large stope, and 2 shafts connecting with the adit level, were made while mining lead ore. Small tabular crystals of wulfenite occur in open fractures in dolomitized limestone in the drifts off the adit, near a large ore shoot consisting of pods of galena up to 2 feet thick in a breccia zone which parallels the bedding. Oxidized lead and copper minerals also are present locally. The wallrock is limestone of the Bird Springs Member of the Monte Cristo Formation.

Hoosier Mine

The Hoosier Mine is in the west-central part of Sec. 4, T. 25 S., R. 58 E. There are three adits and several stopes made while mining lead and zinc. Wulfenite has been observed with galena, cerussite, and hydrozincite along a breccia zone in dolomitized limestone about 200 feet above the base of the Pennsylvanian Bird Springs Formation. The deposit is thus higher in the stratigraphic sequence than any other deposit in the district.

Hermosa Mine

The Hermosa mine is in NW corner Sec. 4, T. 25 S., R. 58 E., 3,000 feet north of the Hoosier mine. Some lead ore has been mined. Cerussite, wulfenite, galena, and pyromorphite occur in a breccia zone trending north to northeast and dipping west in dolomitized Bird Springs Limestone.

Milford Mine

The Milford mine is in the NW 1/4 Sec. 5, T. 26 S., R. 58 E. at the extreme southwestern edge of the Goodspring district. The mine workings consist of a 380-foot inclined shaft with four levels and five stopes, and several adits, made while mining lead-zinc ore. The five ore bodies are in

breccia zones along the contact between the Bullion Dolomite and Anchor Limestone Members of the Monte Cristo Formation. In addition to the galena and lead and zinc oxidation minerals that are common elsewhere in the district, sphalerite was found on the 200-level. Wulfenite is locally abundant.

CRESCENT MINING DISTRICT, CLARK COUNTY

The Crescent mining district is in Ts. 28 and 29 S., R. 61 E., ~~east~~ west of Searchlight along the California-Nevada line (see U. S. Geological Survey Crescent Peak 1:62,500 topographic quadrangle map). Considerable turquoise has been mined from the Crescent Peak area; other mineral production has been small. Precambrian granite and other metamorphic rocks, veneered by Quaternary pediment gravels, are exposed throughout the district. A Tertiary (?) or Mesozoic (?) granite stock apparently intrudes the Precambrian rocks at Crescent Peak.

Crescent Peak

Crescent Peak is in Secs. 26, 27, 34, and 35, T. 28 S., R. 61 E. The Peak is the highest point in the district, with an elevation of 5,999 feet. Considerable turquoise has been produced intermittently from shallow workings on the south slope of Crescent Peak since prehistoric times; there has been little activity in recent years. Interest now is centered on the possibility of locating a porphyry-type deposit in the altered area in which the turquoise is found. In 1954, Bear Creek Mining Company drilled three holes in the heart of the altered zone. During the winter of 1962-1963 the Homestake Mining Company explored the same area with three 1,000-foot diamond-drill holes (a fourth 1,000-foot hole was drilled in the smaller altered area to the southeast).

Strong fracturing and intense alteration is present over an area of three-quarters of a square mile on Crescent Peak, and in a much smaller area a half mile to the southeast (Figure).

Figure . Generalized geologic map of the Crescent Peak area showing holes drilled by Bear Creek and Homestake Mining Companies.

Rocks.

Fresh Precambrian granite surrounds the altered area: within ~~whether~~ the altered area itself is ~~intrusive Precambrian granite~~ or a younger ~~Mesozoic (?) or Tertiary (?)~~ 99 m.y. old (Krueger and Schillin 1971, p. 14) ~~granitic~~ quartz monzonite intrusive; (its extent is not) ~~is not~~ clear because of the obscuring effects of the alteration. ~~Thin section work suggests that a younger intrusive does crop out over at least part of the altered area [illegible]~~). ~~Younger (?)~~ Non-gneissoid biotite quartz monzonite also (?) is found in drill-core from the Homestake exploration holes, and appears to form an irregular body having an interfingering ~~or gradational (?)~~ contact with the Precambrian granite (P. R. Miller, personal communication).

Much of the Precambrian granite is medium- to fine-grained, gneissoid, and consists mainly of quartz and K-feldspar, minor amounts of sodic plagioclase and muscovite, and locally abundant biotite. Lenses of pegmatite consisting of feldspar, mica, and/or quartz, and large veins and lenses of quartz, occur throughout the Precambrian granite, and appear to be late-stage differentiates of the granite. Xenoliths of hornfels, schist, and metaquartzite, up to five hundred feet across, also are common in the granite. ~~Diorite (?)~~ Lamprophyre dikes intrude the granite, and have been effected by the alteration.

Structures.

The altered area is strongly faulted and fractured. Sheeting is common throughout the altered rock but is rare elsewhere; three or more sets of sheeting usually are present in any given spot. Many of the surfaces show small movements. The major faults in the altered zone and surrounding rock mostly are oriented either N. 70° E. with steep dips to the north and south, N. 70° W. with dips mostly 50-70° north, or N. 45° W. with dips of 50-60° northeast. ~~One~~ Two areas within the altered rocks may be breccia pipes — more study is needed before a definate determination can be made.

Alteration.

The alteration occurs as two zones: (1) an inner core of argillization and coarse sericitization about 1,500 feet across; and (2) an outer zone of silicification, K-feldspathization, and fine-grained sericitization which is 1,000 to 2,000 feet wide (Figure). It is not clear whether the alteration now present is due mostly to hypogene processes, or to a great extent to further alteration by the acidic supergene solutions formed during the oxidation of the sulfide mineralization.

In the core the feldspars have been almost completely replaced by clay minerals and/or coarse sericite, giving the rock an earthy, bleached look. Argillization and sericitization occur together, but just as commonly one or the other predominates or is found alone.

In the outer zone the feldspars have been partially replaced and the quartz grains corroded by fine-grained quartz, sericite, and K-feldspar, giving the rock a lighter color. The K-feldspathization is distributed more irregularly and is less common than the other alteration. Hydrobiotite has been introduced in and near the quartz veinlets. Quartz flooding has permeated much of the rock in the outer zone, corroding the feldspar crystals without altering the uncorroded part of the crystals. In a general way flooding is less common along the outer and inner margins of the zone. The flooded rock is "freshened", and made more resistant to erosion; the crescent-shaped ridge-crest of Crescent Peak is the topographic expression of the band of most intense silicification.

On the north and east sides of the Peak, there is a halo of weak alteration extending outward over 500 feet from the altered area. Here, alteration occurs along more widely-spaced fractures, but seldom extends more than an inch in the wall rock.

Mineralization.

The mineralization within the altered area is of the "porphyry" type. Quartz veinlets form a stockwork throughout the altered area, and extend to a depth of at least 1,000 feet. At the surface the quartz veinlets appear to be considerably more abundant in the argillized core than in the outer zone (N. L. Archbold, personal communication), but in Homestake's exploration holes stockwork veinlets were as common in the two holes that penetrate the inner margin of the outer zone, as in the hole drilled in the center of the argillized core.

Below the zone of oxidation, pyrite, sparse chalcopyrite, and locally abundant bornite grains are disseminated irregularly through the wall rock. Molybdenite occurs along the edges of the quartz veinlets, and is locally abundant.Hydrobiotite (?) and epidote are locally abundant in and next to the veins. The Homestake drill hole in the argillized core of the altered area encountered little chalcopyrite, bornite, or molybdenite, and only moderate amounts of pyrite, suggesting that the argillized core is "barren" (drill-core from this hole averaged 0.008 percent copper, 0.008 percent molybdenum, and 0.002 ounces of silver and a trace of gold per ton, below the zone of oxidation). In contrast the Homestake holes in the inner margin of the outer zone encountered 5 to 10 foot intervals of 0.1 percent molybdenum, and have a higher average copper grade, as well as more abundant pyrite, suggesting that the silicified outer zone may be more highly metallized (drill-core from these holes averaged 0.020 percent copper, 0.013 percent molybdenum, and traces of silver and gold, below the zone of oxidation.) Below the zone of oxidation, two of the three holes showed no significant changes in metal values with depth; the easternmost hole however showed an apparent decrease in both copper and molybdenum with depth.

Oxidation.

Oxidation extends to a depth of about 200 feet, however unoxidized sulfide minerals are common below 50 feet. Turquoise is scattered through the altered area, but is mainly in the argillized core (N. L. Archbold, personal communication). Copper-oxide stains are rare, but "limonite" is widespread and abundant, giving the altered area a yellow-brown color. Chalcopyrite boxworks are relatively rare over the surface of the "barren"

Figure . Variations in copper and molybdenum grade with depth in the Crescent Peak altered area.

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argillized core, but common in the inner third of the outer zone of alteration, supporting the thesis that the outer zone is more highly metallized. A few flakes of fresh molybdenite have been observed in the surface croppings (N. L. Archbold, personal communication). Ferrimolybdite and molybdian "limonite" undoubtedly are present, but are difficult to visually identify because of their similarity to other iron oxides. Limonite-cemented gravels containing up to 0.05 percent copper, but no (?) molybdenum, are found along washes "downstream" from the altered area, and apparently were formed by the leaching of the iron sulfides in the altered zones, lateral transportation by surface waters, and redeposition in stream gravels.

There is no significant change in molybdenum grade in passing from the oxidized zone into protore, at least in the Homestake drill-holes (Figure). This absence of a molybdenum-enriched zone, as well as a leached zone, is typical of many molybdenum deposits, although in this case it may be due to the incompleteness of oxidation. In many cases the molybdenite has been oxidized in situ, but locally the oxidation products have been transported short distances downward, resulting in leached material, and thus lower molybdenum values, at the immediate surface.

In contrast, copper values are significantly higher in the upper 50 to 100 feet of the oxidized zone. There is no leached zone below this "enriched" zone (Figure). As has been pointed out above, oxidation has been incomplete and abundant pyrite remains. Under arid conditions decomposition is greatly inhibited by the scarcity of acid, and the lack of water also makes it difficult to move the sparse decomposition products formed more than short distances. Apparently the enriched zone is the result of copper from the upper, now-eroded part of the deposit being "fixed" as turquoise; even incomplete leaching over a few tens of feet would be sufficient to account for the increase in grade.

Conclusions.

Additional drilling is needed, "outward" from the present holes, before possibilities can be properly evaluated. In porphyry-type deposits, molybdenite commonly is associated with silicification and K-feldspathization; only the innermost margin of the zone containing these types of alteration at Crescent Peak have been explored by drilling. The drilling suggests that molybdenum values increase outward; this is a common pattern in many porphry-type deposits.

The molybdenum grade at the surface of the outer zone is too low to be mineable, and this has been used as an argument against further exploration. It is true that the molybdenum grade in the oxidized zone of a deposit commonly is the same as that of the primary mineralization below, but in many cases leaching and migration has taken place at the immediate surface, and an impoverished zone only a few feet deep is present.

Cumberland Mine

The Cumberland (Oro Fino) mine is 1 3/4 miles east of the site of the ghost town of Crescent in SW 1/4 Sec. 22 and NW 1/4 Sec. 27, T. ~~16 N.~~ 26S, R. 61 E.

(see U. S. Geological Survey, Crescent Peak 1:62,500 topographic map). The mine is developed by a 137-foot, inclined (30°) shaft and about 350 feet of subsidiary workings. About $1,000 worth of gold ore reportedly has been produced (Vanderburg, 1937, p. 24).

Narrow quartz veins containing gold and subsidiary silver, lead, and copper values cut Precambrian gneiss in a pediment extending west from Crescent Peak. The ore is highly oxidized and contains considerable calcite. Specimens of ore from the dump showed vanadinite and wulfenite.

Budget Mine

The Budget mine is 2 miles south of Crescent Peak in Sec. 2, T. 29 S., R. 61 E. (see U. S. Geological Survey, Crescent Peak 1:62,500 topographic map). The mine consists of several adits and shallow shafts totalling about 600 feet at workings. About 200 tons of ore containing 1 1/2 ounces gold, 2 ounces silver, and 3 1/2 percent lead was shipped in the 1930s.

The ore is in a quartz vein striking N. 25 E. and dipping 35°-50° in Precambrian granite gneiss. The vein is a few inches to 2 feet wide, and averages 8 inches. The vein material is oxidized and consists mainly of quartz, "limonite", and manganese oxides. Wulfenite and vanadinite (?) occur in the vein filling. (Vanderburg, 1937, p. 20).

SEARCHLIGHT MINING DISTRICT, CLARK COUNTY

The Searchlight mining district is in a group of hills on the east side of Piute Valley in the southern part of Clark County. Most of the mines and prospects are in Secs. 22, 27, and 34, T. 28 S., R. 63 E., and Secs. 2 and 3, T. 29 S., R. 63 E. (see U. S. Geological Survey, Searchlight 1:62,500 topographic quadrangle map). The town of Searchlight is in the southern part of the district. It is accessible from Nipton, California, 21 miles to the west on the Union Pacific Railroad, via State Highway 68, and from Las Vegas, 55 miles to the north, via paved U. S. Highway 95. The district, discovered in 1897, has produced over $4,500,000 worth of gold, silver, copper, and lead. The principal value was in gold except in a very few veins.

Geology. Callaghan (1939) described the geology of the district, and the individual mines and prospects in some detail, the following description being principally from his report.

Precambrian granite gneiss is overlain by early Tertiary (?) andesitic flows and breccias (fig.). These rocks were intruded by andesite prophyry. A large mass of early Tertiary (?) quartz monzonite intruded both the andesite porphyry and earlier rocks. After a period of erosion, a second series of volcanic rocks were extruded during the late Tertiary (?).

The contact of the quartz monzonite body is very irregular, numerous

Figure . Generalized geologic map of the Searchlight mining district.

dikes and sills projecting into the intruded rocks. The margins of the body are porphyritic, the size and proportions of the phenocrysts varying irregularly. The quartz monzonite consists of quartz, orthoclase, oligoclase, andesine, biotite, augite, magnetite, apatite, and zircon. The augite has

been altered to hornblende. Chlorite replaces the ferromagnesian minerals. The orthoclase and plagioclase are present in approximately equal amounts. The quartz is interstitial to the feldspar and graphically intergrown with the orthoclase. Biotite is more abundant than the augite.

A study (Shrivastava and Proctor, 1962) of the trace element distribution in the quartz monzonite stock shows that Mo (10-20 ppm) and V (250-1,000 ppm) occur almost entirely in the magnetite; that Ni, Co, Mn, and Ti are essentially confined to the mafic minerals and magnetite; that Cu has its greatest concentration (20-70 ppm) in augite, hornblende, and chlorite, and also occurs in appreciable amounts (5-25 ppm) in the magnetite, biotite, quartz, and feldspars; and that Pb is most abundant (up to 155 ppm) in the mafic minerals (including magnetite), but also is fairly rich (38 ppm average) in the feldspars.

The veins are distributed in an en echelon pattern around the western, northern, and southern margins of the quartz monzonite body. A few small veins occur along the east side of the body. Most of the veins and many of the apophyses of the quartz monzonite body fill fractures striking west and dipping to the south; a few veins fill fractures striking north and dipping to the west. The fractures are of the gash type with maximum displacement in the center and decreasing movement toward the ends and with depth. During regional movements following the consolidation of the quartz monzonite, the body apparently acted as a competent mass, so that fractures formed in a regular pattern in the less competent rocks around its margins. Movements along the fractures after the formation of the veins has brecciated the vein material and adjacent wall rock.

The largest veins are in the early Tertiary (?) volcanic rocks and andesite porphyry, are up to 50 feet wide, and have been productive over some 1,000 feet along their strike and mined to a maximum depth of 900 feet.

The veins consist of brecciated country rock cemented by porous and vuggy quartz. Later movement has brecciated the quartz. Some adularia and calcite also occur in the veins. Except in a few limited areas, the veins are almost completely oxidized, secondary lead, copper, and iron silicates, sulfates, and carbonates filling fractures and cavities in the veins. The primary sulfide minerals galena, sphalerite, and chalcopyrite occur locally in the quartz. Cerussite and hemimorphite are the most abundant secondary minerals. A great variety of other oxidation products are present, including chrysocolla, chalcocite, cuprite, hematite, malachite, brochantite, linarite, leadhillite, wulfenite, vanadinite, and mottramite.

The country rock in which the veins occur have been altered by emanations from the quartz monzonite, by the vein-forming solutions, and by supergene solutions during the weathering of the primary mineralization. Epidote, quartz, and magnetite were formed in the volcanic rocks around the periphery of the quartz monzonite body, but bear no relation to the veins.

Wall-rock alteration in the southern part of the district is slight; in the northern part of the district the volcanic rocks and andesite porphyry have been altered to a fine grained aggregate of adularia and quartz containing remnants of primary minerals.

The later supergene alteration has changed the feldspars in the wall rock to beidellite-type clays. The adularized and silicified rock in the northern part of the district have not been affected to any extent by the supergene solutions. The wall rock along the northern veins is stained brown and yellow, the staining being pale green or gray in the southern part of the district.

The vein minerals and wall-rock alteration both vary from north to south in the district. (The zonal distribution of the wall-rock alteration is mentioned above) ~~under Alteration~~. The amount of primary copper sulfides

in the veins apparently decreased northward, the northern veins containing only minor amounts. The copper content of the quartz monzonite stock apparently also originally decreased northward, however in the now-altered stock the reverse is true and the copper content increases northward (Shrivastava and Proctor, 1962), suggesting that copper was removed from the stock during the alteration that took place as the stock cooled and was redeposited in what is now the veins.

Specular hematite is abundant in the Quartette mine in the southernmost part of the district but is rare elsewhere. Calcite is much more abundant in the northern veins than in the southern veins. These mineralogical changes appear to be gradational. There was considerably more gold than silver in the ores from the southernmost and northern parts of the district, however, at the Duplex mine in the south-central part of the district, silver is slightly more abundant than gold.

The zoning is not distributed radially in respect to the outcrop of the quartz monzonite. Callaghan (1939) believed that the Quartette vein in the south was deposited at higher temperatures than the veins at the Pompeii and J. E. T. mines in the northernmost part of the district. It is interesting to note that wulfenite is most abundant in the "higher temperature" Quartette vein, occurs in the Duplex mine a short distance to the north, but reportedly is very rare to absent elsewhere in the district.

Quartette Mine

The Quartette (Golden Treasure) mine is mostly in Secs. 2 and 3, T. 29 S., R. 63 E., and is the southernmost mine in the district. Approximately 65 percent of the gold, 20 percent of the silver, 60 percent of the copper, and 15 percent of the lead produced in the district have come from this mine. Nearly all the total production of over $2,800,000 took

place from 1902 through 1923. The mine is developed by extensive workings totaling over 5 1/2 miles. There are 13 levels which explore the vein for 2,100 feet along the strike and for 1,160 feet down dip, reaching a depth of 870 feet. A great deal of stoping was done (see Callaghan, 1939, plates 45 and 46 for plan and section of the mine). Nearly the entire mine is now flooded.

The country rock is volcanic rocks altered to hornfels, gneiss, and andesite porphyry dikes. The vein is 3,300 feet long on the surface. It has a general N. 70° W. strike, curving to a more northerly strike at its northwestern end, and dips 40°-72° S., with dips of 50°-60° throughout most of its length. The vein cuts the irregular gneiss-hornfels contact, and is offset by post-mineral faulting. Splits are common, as are quartz veinlets and gouge seams in both the hanging and foot walls.

The main orebody, or group of ore shoots, was in the western part of the vein, extended from near the surface to a point about 1,000 feet downdip, had a maximum width of 700 feet, and pitched to the south. Ore shoots up to 50 feet wide were stoped, the largest stopes apparently being at splits. The vein pinches laterally and downdip.

The vein consists of brecciated country rock cemented by porous and vuggy quartz which, in turn, has been brecciated. The quartz is widely distributed, but never forms large or solid masses. Abundant chrysocolla and "limonite" and some malachite stain the quartz. Large masses of cerussite locally are common in the veins. Earthy cuprite and radial aggregates of hemimorphite are present. Abundant plates and sheafs of specular hematite occur in the quartz. A little chalcopyrite and some residual kernels of galena are found in a few limited areas. Silver values are higher where cerussite or galena are present.

REPORT SUBJECT TO REVISION

Ransome (1907, p. 71) states that:

> Wulfenite, the molybdate of lead, in characteristic square, tabular orange-colored crystals, is very common throughout the mine and does not necessarily indicate ore. It is apparently one of the later products of oxidation and occurs in little vugs and open fissures, implanted on the other minerals.

Duplex Mine

The Duplex (IXL) mine is mainly in the southwest corner of Sec. 34, T. 28 S., R. 63 E., on the hill south of the town of Searchlight. The mine is the second largest in the district, both in production and extent of the workings. The total production, reportedly exceeded $650,000, chiefly in gold, but with important values in lead, and lesser values in silver and copper. The mine produced intermittently from 1903 to 1934. The mine is developed by extensive workings extending over 1,600 feet laterally and to a depth of over 700 feet (see Callaghan, 1939, figs. 24 and 25 and plate 49 for sections and plan of mine).

The country rock is pyroclastic rocks altered to hornfels and andesite porphyry dikes. There are 4 veins; 3 of the veins generally strike N. 60°-70° W. and dip 45°-75° W. The other (IXL) vein strikes N. 8° W. and dips 10°-25° W.

The New Years Gift vein, the northernmost of the four, was by far the most productive. The ore body extended from the surface to a depth of 500 feet, has a maximum lateral extent of 1,200 feet at a depth of 300 feet, pitches 10° E., and is up to 10 feet wide with an average width of 4 or 5 feet. The vein consists of brecciated country rock cemented by quartz. Chrysocolla and some malachite stain the quartz. Lumps and large masses of cerussite are common. A few lumps of coarse galena are found locally. Zinc is present as hemimorphite and films of mottramite.

The Fraction, the next vein to the south, intersects the more gently dipping New Years Gift vein. It has been stoped at the surface and above the

intersection. The orebody has a maximum lateral extent of 400 feet and pitches 10° E. The vein material is similar to that of the New Years Gift mine.

Only a small amount of stoping was done on the Searchlight vein which is the next vein south of the fraction. Apparently no stoping was done on the IXL vein, the southernmost vein in the mine.

Wulfenite occurred sparingly in the veins as tabular orange-yellow crystals. The average metal content of the ore shipped was 4.0 ounces of gold and 6.9 ounces of silver per ton, 11.8 percent lead, 2.9 percent copper, and 1.6 percent zinc. The silver content was higher in the ore that was richer in lead.

OTHER OCCURRENCES, CLARK COUNTY

Charleston Peak

Molybdenite reportedly occurs with pyrite in a quartz vein near Charleston Peak, which is the highest point in the Spring Mountains (on some maps the northern half of the Spring Mountains are labled the Charleston Mountains or Charleston Range). Nothing more is known about this occurrence; it could not be located in the field. There are a few small base metal deposits in this area, and a little lead has been produced.

Key West Mine

The Key West mine is in NE 1/4 Sec. 21 and NW 1/4 Sec. 22, T. 15 S., R. 70 E. in the low rolling foothills along the northwestern flank of the Virgin Mountains (see U. S. Geological Survey Virgin Peak 15-minute quadrangle). Copper-nickel-cobalt-platinum ore has been mined from the extensive underground workings and small open-pit. Chalcopyrite, pyrite, pentlandite, pyrrhotite (?), polydymite, minor magnetite, and rare sphalerite occur in quartz-carbonate veins, mainly in a Precambrian hornblendite (dunite, peridotite) dike, and to a lesser extent in the granodiorite gneiss that the dike intrudes (Beal, 1965, p. 67-73). A little disseminated molybdenite was noted in several specimens of the hornblendite (Lindgren and Davy, 1924). Azurite, malachite, brochantite, chalcanthite, chysocolla, cuprite, erythrite, and garnierite are found in the oxidized zone. The mineralization is confined chiefly to a highly shattered area containing a maze of faults with varying orientations. The dike is extensively propylitized, silicified, and dolomitized.

Lucy Gray Mine

The Lucy Gray mine is in Sec. 32, T. 27 S., R. 60 E., in the mountains 3 miles ~~northeast~~ southeast of Desert, California, a siding on the Union Pacific Railroad (see U. S. Geological Survey, Roach Lake 15-minute quadrangle). Over three thousand feet of underground workings were made while mining gold ore.

Numerous vuggy quartz veinlets form a stockwork in a pipelike shattered zone in Precambrian granite gneiss. The "pipe" is elliptical in plan, is 150 by 200 feet across, with the long axis trending northwest. Few of the rock fragments are more than a foot in diameter; the boundary between the highly-brecciated and undisturbed rock is quite sharp. Limonite-stained fractures cutting the quartz veinlets and rock fragments contained the gold values. In the Lucky Shaft (SW 1/4 Sec. 32) wulfenite and vanadenite locally coat quartz and granite gneiss. Elsewhere in the mine minor pyrite, galena, and chalcopyrite occur with the quartz stockwork.

Marron Tungsten Prospect

The Marron Tungsten prospect is in Sec. 18, T. 20 S., R. 71 E., in the Gold Butte mining district. Scheelite and powellite are found in joints and fractures in and near granitic dikes that cut Precambrian schist.

DOUGLAS COUNTY

Risue Canyon

Molybdenite and powellite occur in the scheelite-bearing tungsten deposits along both sides of the California-Nevada line southeast of Topaz Lake. Most of the tungsten deposits are in California; here the molybdenite is in quartz veins cutting the tactite containing the scheelite.

Tactite is much less common in Nevada. It occurs in limestone and metamorphic rocks in contact with irregular dike-like masses of quartz monzonite. Locally the tactite contains small amounts of scheelite. Small amounts of molybdenite undoubtedly also are present, probably in the many quartz veinlets that locally cut the tactite.

Gardnerville Mining District

American Metal Climax encountered molybdenite mineralization in "granite" in drill holes drilled near the contact-tungsten deposits 12 miles southeast of Gardnerville on the west flank of the Pine Nut Range. Most of the drilling has been done in the south-central part of sec. 36, T. 12 N., R. 21 E.

1/ breccia pipe
2/ porphyry molybdenum
on fault of porphyry body

MOUNTAIN CITY MINING DISTRICT, ELKO COUNTY

A large body of Cretaceous ~~Mountain City~~ quartz monzonite (the Mountain City stock) outcrops in the Mountain City mining district of northwestern Elko County (see Fig. ____).

Figure ____. Generalized geologic map of the Mountain City-Contact belt of intrusives and molybdenum occurrences.

Molybdenite has been reported at several spots in the southeast margin of the intrusive.

Huber Hill

An adit was driven, and bulldozing and drilling were done, at the head of Schlag Draw, 2 miles east of Mountain City, while exploring for molybdenum and copper. Several short diamond drill holes were drilled downward from the adit which is several hundred feet long. Molybdenite occurs with pyrite and minor chalcopyrite in quartz veinlets forming a stockwork in altered quartz monzonite. Some molybdenite also is disseminated through the quartz monzonite. The mineralization exposed is sparse and limited to a rather small area.

Golden Ensign Mine

Molybdenite reportedly is present at the Golden Ensign mine which is 1 1/2 miles southeast of Mountain City. Apparently the molybdenite was in a vein in the Mountain City stock which also carried gold and silver values. This occurrence could not be located.

JARBIDGE-TENNESSEE MOUNTAIN AREA, ELKO COUNTY

A number of tungsten contact deposits occur on the margins of the cretaceous Coffeepot quartz monzonite stock in north central Elko County. The tungsten-bearing tactite occurs in argillaceous limestone and limy shale of the Paleozoic Tennessee Mountain Formation (Bushnell, 1967) along the south contact of the stock which is elongate east-west. The tactite occurs as dense, purplish, streaked lenses consisting mostly of garnet, but containing considerable pyroxene, hornblende, calcite, diopside, and quartz, and minor chlorite, actinolite, epidote, and plagioclase; scheelite, powellite, molybdenite, chalcopyrite, and pyrite are present locally.

Figure __. Generalized geologic map of the Coffeepot stock and associated ore deposits (after Bushnell, 1967, and Coats, 1964).

It is interesting to note that the intrusive is leucrocratic near the tactite suggesting a loss of iron and magnesium to the tactite (Bushnell, 1967).

Coon Creek Mine

The Coon Creek (Rowland) mine is located in W 1/2 sec. 6, R. 58 E., T. 45 N. between Coon Creek and the road from Charleston to Jarbidge. There are two shallow shafts and several hundred feet of open cuts. Four tons of ore averaging 3.8% WO_3 after sorting have been produced.

Limestones and shales have been altered to garnet, epidote, quartz, and calcite in a zone up to 100 feet wide along the contact of the Coffeepot stock. A number of small faults cut the stock and sedimentary rocks causing a "chopped-up" pattern. Finely disseminated scheelite and associated molybdenite, powellite, pyrite, and chalcopyrite are scattered irregularly through the tactite.

Batholith Mine

The Batholith mine is in secs. 13 and 14, T. 45 N., R. 57 E. just southwest of Coon Creek Summit on the Charleston-Jarbidge road. Some scheelite has been produced from the open pits that make up the mine. Molybdenite and powellite occur with scheelite in tactitized limestone in contact with quartz monzonite. It is not clear whether the quartz monzonite is part of the Coffeepot stock or an outlier as much of the area to the northwest is covered by glacial debris.

Tennessee Mountain

A number of tungsten prospects are scattered along the contact of the Coffeepot stock in secs. 5, 6, 7, 8, 16, 17, 21, and 22, T. 45 N., R. 56 E. on the west and south flanks of Tennessee Mountain. From northwest to southeast these include the Mowhawk, Apex, Garnet, and Little Joe prospects. Production if any has been small.

Interbedded limestones, shales, and quartzites of the Paleozoic Tennessee Mountain Formation, striking north to northeast and dipping 45° NW to vertical, are in contact with the quartz monzonite stock. Sills and dikes up to 20 feet thick of the quartz monzonite extend out into the sediments. Aplite dikes cut the dikes, sills, and sediments and appear to be late stage differentiates from the quartz monzonite stock.

The sediments have been contact-metamorphosed in a zone 50 to 100 feet wide along the contact of the stock, up to 25 feet wide along the sills and dikes of quartz monzonite, and up to 5 feet wide along some of the aplite dikes. The limestone and more limy shale ~~has~~ have been altered to garnet-rich tactite and the remaining shale to hornfels.

Scheelite occurs in the tactite along the contacts of the stock, dikes, and sills, both as large masses and as small disseminated grains forming bands that parallel bedding and are separated by layers of hornfels and barren

tactite. Most of the scheelite is concentrated within 20 feet of the stock and within 5 feet of dikes and sills, and rapidly diminishes in quantity beyond these distances. Scheelite also is present as scattered grains in quartz and calcite veinlets that cut the tactite. Locally these veinlets are abundant enough to form stockworks.

Molybdenite, pyrite, and minor chalcopyrite are present in the tactite and veinlets. The distribution of these minerals bears no apparent relation to the presence or absence of scheelite. Higher than average concentrations of molybdenite are found on the Mowhawk and Garnet prospects.

CONTACT MINING DISTRICT, ELKO COUNTY

The Contact mining district is around the town of Contact in northeastern Elko County. Most of the mines and prospects, including all the reported occurrences of molybdenum, are west and southwest of the town in T. 45 N., Rs. ~~14~~ 63 & ~~15~~ 64 E. The town of Contact is on U. S. Highway 93 and the Union Pacific Railroad.

History. The mineral deposits in the district were discovered about 1870. Approximately half a million dollars worth of ore have been produced, mostly from 1913 through 1930. The values were mainly copper with some silver, lead, and gold.

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Geology. Carboniferous limestone, quartzite, and shale are intruded by a granodiorite stock 6 to 7 miles wide north-south and about 18 miles long east-west. Apophyses of the granodiorite extend out from the stock into the surrounding rock. Alaskite dikes cut the granodiorite and

Fig. ___. Generalized geologic map of the Contact mining district showing mines and molybdenite occurrences.

sedimentary rocks, and probably represent a late phase of the igneous activity that included the intrusion of the granodiorite. Tertiary (?) andesite dikes cut the alaskite dikes and older rocks. Tertiary volcanic and sedimentary rocks locally cover the other rocks (Schrader, 1912 and 1935).

The granodiorite is speckled gray, has a hypidiomorphic texture, and consists of approximately 55 percent zoned oligoclase-andesine, 20 percent interstital quartz, 10 percent perthitic orthoclase, 15 percent biotite and hornblende, and some apatite and titanite. Biotite from the intrusive was dated as 152 m.y. using the K-Ar method; zircon from the same sample gave a lead-alpha age of 160 m.y. (Coats, Marvin, and Stern, 1965).

The alaskite dikes are pale pink to light gray, porphyritic, are commonly less than 5 feet wide, but up to 5 miles long, and consist of equal amounts of orthoclase and oligoclase, less than 10 percent quartz, less than 5 percent biotite and hornblende, and some titanite, apatite, zircon and magnetite.

The Carboniferous sedimentary rocks have been domed along an axis trending due east and having the granodiorite stock at its center, the doming apparently resulting from the intrusion of the granodiorite.

The alaskite dikes have been intruded along a conjugate fracture system with one set of fractures striking N. 30°-45° E., and the other set striking N. 45°-60° W.

The limestone in contact with the granodiorite stock has been silicified, then replaced by skarn minerals. Actinolite, diopside, wollastonite, garnet, axinite, epidote, chlorite, and recrystallized calcite have been formed. The silicate minerals are mostly in the limestone, but locally also have replaced the adjoining granodiorite. Weathering has altered the skarn minerals to chloropal and kaolin.

Ore Deposits. There are three types of deposits in the district: (1) bodies in or closely related to the areas of contact-metamorphosed rock; (2) fissure veins and disseminated mineralization in or associated with the alaskite dikes; and (3) fissure veins, locally enlarged by replacement, that are not associated with the alaskite dikes. These three types of deposits differ mainly in wall rock and structural detail.

The bodies associated with the contact-metamorphosed rock are 15 to 30 feet thick. Most of these bodies are related to fracturing, and commonly cut across bedding; other bodies show no relation to fracturing, and replace a particular bed. The primary minerals are quartz, chalcopyrite, bornite, and locally small amounts of molybdenite, magnetite, and specularite. Quartz and calcite veinlets cut the bodies. It is interesting to note that pyrite

is rare or absent in all three types of deposits found in the district, and that no tungsten minerals have been reported in the contact-metamorphosed limestone.

The deposits related to the alaskite dikes are veins following fissures in and parallel to the dikes, and disseminations in fractured and altered dike rock. These deposits are mainly in the granodiorite and alaskite dikes themselves, but also occur in the limestone. The primary minerals are quartz, chalcopyrite, molybdenite, and specularite.

The fissure veins that are not associated with alaskite dikes most commonly are in unmetamorphosed limestone, but also are in the granodiorite and contact-metamorphosed limestone. These veins are 1 to 10 feet thick. Although there has been some wall-rock alteration and deposition of skarn minerals, quartz is the most abundant introduced mineral. Some of these veins are similar mineralogically to the other two types of deposits in the district; other veins, low in copper, originally contained galena, lesser sphalerite, and possibly some argentite, but these minerals have been largely destroyed by oxidation.

Oxidation has taken place to depths of 150 to 250 feet in all three type deposits. Chrysocolla, malachite, azurite, chalcocite, cuprite, and native copper have been formed from the primary copper mineralization. Cerussite is the principal oxidation product of the primary lead mineralization. Hematite and limonite are common, and manganese oxides are abundant locally. In some cases, the oxidation products have migrated some distance.

Alice Mine

Becky

At the Alice mine, leaf-like veinlets of molybdenite, forming a "mesh", are intergrown with malachite, azurite, and a little chalcopyrite, bornite, chalcocite, and covellite. These minerals form vertical bands and irregular stringers up to a foot wide in an 8-foot wide body of contact-metamorphosed limestone.

Bonanza Mine

In an inclined winze in the upper west workings of the Bonanza mine, small amounts of molybdenite occur with secondary copper minerals and some copper sulfides in contact-metamorphosed limestone along the contact of the granodiorite stock. An alaskite dike cuts the mineralized rock.

Copper Shield Group

In the southern part of the Copper Shield (Effie Fay) group, some molybdenite is associated with quartz, secondary copper minerals, bornite, chalcopyrite, and specular as banded mineralization in an alaskite dike.

Florence Group

In the Florence No. 16 claim, considerable molybdenite is present in an alaskite dike, in the more hematitic portion of a vein consisting of copper carbonates, oxides, and sulfides, and chrysocolla, in glassy quartz and hematite.

Helen B. Smith Tunnel

In the Helen B. Smith Tunnel, a little molybdenite occurs with specks of chalcocite and some chalcopyrite, bornite, and covellite in granodiorite. However, most of the copper mineralization exposed by the Tunnel is in contact-metamorphosed limestone, and apparently contains no molybdenite.

Ivy Wilson Group

In the Ivy Wilson group, chalcopyrite and some associated molybdenite and bornite are disseminated irregularly through a 400-foot by 6,000-foot area in contact-metamorphosed limestone. This zone is 1,200 feet west of the granodiorite stock, and parallels both the bedding in the limestone and the granodiorite contact.

Six hundred feet north of the tunnel in the "sulfide" zone, molybdenite is disseminated in a 1- to 3-foot, garnetized quartzite(?) bed. The beds on both sides of the quartzite bed contain disseminated chalcopyrite and bornite.

Mammoth Mine

At the Mammoth mine, some molybdenite is associated with bornite, chalcopyrite, copper carbonates, and chrysocolla in contact-metamorphosed limestone. These minerals are more abundant along the footwall which is granodiorite.

OTHER OCCURRENCES, ELKO COUNTY

Indian Creek Prospects

The Indian Creek (Montrose, Owyhee) prospects are in the SW 1/4 Sec. 16, T. 45 N., R. 51 E. The two prospects are a short distance apart, and have been developed by small pits and bulldozer cuts. The Anaconda Co. drilled a churn (?) hole in the same area; its location is not known.

Molybdenite, pyrite, chalcopyrite, galena, sphalerite, and rare nicollite occur in quartz veins cutting Paleozoic (?) slate. The molybdenite is rare at the northern prospect, but is much more abundant than the other minerals at the southern prospect. Yellow limonitic stains are common on the quartz. The molybdenite is fine-grained, and occurs in masses up to several inches across. These masses appear to be leached --- that is they are spongy or porous, and have a very dull "weathered" luster --- however, except for minor staining, no residual oxidation products remain in or on the molybdenite. Bedrock relationships are badly obscured by soil; the quartz stringers appear to strike east-west, and the slate appears to be more altered than in exposures along Indian Creek.

The slate is unconformably overlain by Tertiary basalt flows. The basalt seldom is more than a few tens of feet thick, and the mineralization is exposed in small "windows" in the basalt. Topographically the windows are shallow depressions, a few feet deep and less than 50 feet across, in a flat plain which has been only slightly dissected by erosion. To the southeast Indian Creek has eroded a deeper valley into the slate.

Robinette Prospect

The Robinette (Pyramid) prospect is in the Elk Mountain mining district on the west flank of White Elephant Butte (or Mountain) in Sec. 4, T. 46 N., R. 61 E.

The district was discovered in 1890. Early interest was in copper, gold, and silver. Later tungsten was found on the Robinette claims, and a tungsten mill was built at the head of O'Neil Creek by Pyramid Tungsten, Inc., of Yakima, Washington. Considerable ~~stripping~~ trenching has been done on the claims and there are 5 adits made while searching for molybdenite and scheelite -- the longest is 65 feet.

In the district (see Fig. ____) a stock of granodiorite, which is exposed over a 3/4- by 1 1/2-mile area, intrudes and domes Paleozoic shale, limestone, quartzite, and slate. Copper, gold, silver, antimony, tungsten, and molybdenum ~~deposits~~ are found along the granodiorite-sedimentary contact, most commonly in the limestone.

At the Robinette prospect small specks of molybdenite, psuedomorphs of white powellite replacing flakes of molybdenite, and small grains of scheelite are sparsely disseminated throughout a lens of tactitized limestone along a N. 50° E.-trending contact with the granodiorite stock. At the south end of the tactite body, in the vicinity of a 50-foot adit, appreciable amounts of molybdenite are found in 2-inch-thick quartz veins which trend at right angles to the contact. The veins also contain some pyrite, chalcopyrite, and garnet.

Tecoma Hill Mines

The Lucin mining district is mainly in Utah but the workings of some of the mines on Tecoma Hill extend westward into Nevada (Sec. 24, T. 39 N., R. 70 E.). The district has produced over $4 million worth of copper, lead, silver, and zinc.

no such section on right probably [illegible] Sec. 21

The Tecoma Hill deposits are fissure fillings and replacement bodies in carbonate beds of the Devonian Guilmette Formation, Silurian Laketown Dolomite, and Ordovician Fish Haven Dolomite (Blue, 1960). The ore occurs where east- and northeast-dipping, steeply south- to southwest-dipping faults intersect the favorable beds. The Patterson Pass monzonite-porphyry

stock and associated dike cropout in the area, and appear to be genetically associated with the ore deposits. There has been only slight alteration of the rocks in the vicinity of the mineralization.

The ore deposits have been almost completely oxidized except in a few small areas where primary sulfides still remain. Wulfenite occurs with anglesite, cerussite, smithsonite, plumbojarosite, and limonite, and locally with galena, sphalerite, and pyrite. The wulfenite (Hague and Emmons, 1807, p. 497) "frequently forms so high a percentage of the ore as to interfere seriously with its treatment in the ordinary lead furnaces, rendering a modification of the methods employed very desireable. The crystallized wulfenite from the Tecoma mine occurs in large masses, the faces of the individual crystals having been observed from an inch to 1 1/2 inches in length. They possess a resinous luster, a lemon yellow color, and are frequently transparent and exceedingly brittle. In size and brilliancy the finest specimens far surpass the famous wulfenite crystals of Bleiberg ... . Associated with the wulfenite, adhering to the broad tabular faces, may occasionally be seen well developed crystals of cerussite and anglesite."

Wulfenite specimens from "Tecoma" are in the American Museum of Natural History and the California Bureau of Mines collection (Horton, 1916, p. 89); these were thought to be from the Tecoma mining district of Elko County (Schilling, 1962a, p. 13), but probably are from the mines in Tecoma Hill.

Star Mine

The Star tungsten mine is 2 miles east of Harrison Pass on the east flank of the Ruby Mountains. The mine is developed by an adit, shaft, and drifts totalling about a thousand feet, and numerous small pits, cuts, and trenches. The mine has produced 7,735 units of WO_3.

Scheelite and minor powellite occur in tactite consisting mainly of quartz, garnet, epidote, and calcite. The tactite forms small irregular bodies in Pogonip Limestone along the eastern contact of the Harrison Pass

quartz monzonite stock. A number of dikes and sills extend outward from the stock into the sedimentary rocks. The sedimentary rocks have been metamorphosed to marble and hornfels in a zone extending up to 1,500 feet from the contact. Isotopic age dating indicates that the intrusives and mineralization probably were emplaced some 30 to 40 million years ago during Eocene or Oligocene time (Schilling, 1965b, p. 32-33).

Spruce Mountain Mining District

The Spruce Mountain mining district is in T. 31 N., Rs 63 and 64 E., about 45 miles south of Wells. Over $3,000,000 worth of lead, silver, copper have been produced (Granger and others, 1957).

Wulfenite is found with limonite, cerussite, anglesite, and residual galena. Locally, the copper minerals, malachite, chrysocolla, chalcopyrite, and subordinate quantities of bornite and chalcocite, are present with the lead minerals. The zinc minerals, smithsonite and calamine also are present locally. The ore minerals form oxidized, bedded-replacement bodies in Carboniferous limestone and oxidized fissure veins in the limestones and interbedded sandstones. A 500-foot-wide granite porphyry dike extends east-northeast across the district. Some of the orebodies are on the contact between the dike and limestones.

Dolly Varden Mining District

The Dolly Varden mining district is in Tps. 28 and 29 N., Rs. 65 and 66 E., fifteen miles northeast of Currie in southeastern Elko County. The district has produced less than $100,000 worth of silver, copper, and lead (Granger and other, 1957).

In the extreme southeastern part of the district, oxidized lead-silver replacement deposits consisting of cerussite, anglesite, rare wulfenite, and residual kernals of galena occur along and adjacent to north-trending fractures in Carboniferous limestones (Schrader, Stone, and Sanford, 1917, p. 200). A quartz monzonite stock crops out

in the northern part of the district. Quartz veins containing chalcopyrite, pyrite, and minor bismuthinite, cut the stock; and oxidized contact deposits consisting of chrysocolla, malachite, skarn minerals, and rare kernals of residual chalcopyrite and cuperiferous pyrite, occur in the surrounding limestone and shale. No molybdenum minerals have been reported in the veins or contact deposits, although molybdenite could be expected. ~~(Schrader, Stone, and Sanford, 1917, p. 200).~~

Southam Molybdenum Mine

Kingsley?

The Southam molybdenum mine is in Sec. 13, T. 26 N., R. 67 E. in the Kingsley mining district. Small amounts of copper, tungsten, lead, silver, and molybdenum have been produced from the mine (personal communication, D. H. Adair).

The mines of the district are around the Kingsley quartz monzonite stock in gently-dipping, little disturbed Cambrian limestones and shales. The roughly-circular stock crops out over an area of about one square mile. Contact effects include small irregular tactite bodies and more widespread bleaching and marblization. A swarm of vertical quartz latite porphyry dikes, ranging from 1 to 200 feet in width, and striking N. 40° E., cut the stock and extend up to 1,000 feet into the sedimentary rocks. Most of the ore deposits, including those of the Southam mine, are in limestone near the end of the dikes.

At the Southam mine, molybdenite, copper minerals, scheelite, and galena occur in quartz veins, striking northeast and dipping 55° W., cut marble along the southwest edge of the stock. The veins locally contain up to 35% molybdenite (Steininger, 1966).

CUCOMUNGO AREA, ESMERALDA COUNTY

Cucomungo Deposit

The Cucomungo (Sorensen and Roper properties, Alum Gulch deposit, Tule Canyon deposit, Poison Spring deposit, Siskon property, Chessher property, Cucamungo deposit, Alum Creek deposit) molybdenum deposit is in the Magruder Mountains in the vicinity of Poison Spring, mainly in Secs. 2 and 3, T. 7 S., R. 39 E., southern Esmeralda County. The deposit is accessible from Lida to the north via Pigeon and Log Springs.

The deposit reportedly was discovered in 1917 by Bob Sorensen who located a number of claims. In the 1920's and 1930's, Gus Roper located some claims and drove an adit (the first 220 feet reportedly ran 0.1% MoS_2, the next 110 feet 0.4% MoS_2, the next 50 feet was essentially barren.). In 1938, the Roper claims, which were held by the Nevack Moly Co., were sold at a sheriff's sale to satisfy a $1,678 judgement. In 1939, Freeport Sulphur optioned the Roper and Sorensen groups of claims, extended the Roper adit, and drilled a 200-foot, horizontal hole from the adit face; six other holes were drilled from the surface (fig. __). H. B. Chessher (Siskon Moly Corp.) acquired the Roper claims, and built access roads, drilled several holes, and did some surface sampling.

In 1960, Bear Creek Mining Co. optioned both the Roper and Sorensen properties, and located some additional claims. Fourteen diamond-drill holes were drilled; one hole is 1,438 feet deep, the other holes are less than 800 feet deep (fig. __). In addition a number of shallow wagon-drill holes were drilled. Extensive roads have been built to give access to drill sites. Detailed geologic mapping also was done. Their option was dropped in 1961.

During 1967, the Molybdenum Corporation of America explored the deposit; they resampled some of the Bear Creek core and did additional ~~churn~~ rotary drilling

(fig. __). In 1969 and 1970, Geochemical Surveys, Dallas, Texas, in a joint venture with Pan American Sulphur Co., made detailed geochemical surveys of the area, and drilled thirteen holes (fig. __) west and southwest of the area previously drilled.

Except for the Roper adit which is approximately 900 feet long including several short lateral workings, the only development has been the extensive roads and drill holes. The Roper adit extends northeast from the bottom of Alum Canyon at a point a short distance downstream from Poison Springs.

There has been no production of molybdenum or other mineral commodities.

The Rocks. Paleozoic limestone and shale have been intruded by two stocks which are part of the Jurassic Inyo batholith (McKee and Nash, 1967). The older "Uncle Sam" quartz monzonite porphyry (Sylvania adamellite of McKee, 1962), crops out over a large area southwest of the deposit; the younger, "Cottonwood" granite (Tule granite of McKee) covers a large area at, and east of, the deposit (fig. __). Isotopic age dating indicates that the intrusives are both about 150 million years old (Schilling, 1965). At the surface, the two granitic rocks are separated by a narrow, northwest-trending wedge of sedimentary rocks (fig. __), but drill-hole data indicates that they are in contact at depth. The sedimentary rocks also crop out over large areas northwest to northeast of the deposit (Albers and Stewart, 1965).

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Figure __. Geologic Map of the Cucomungo deposit.

The sedimentary and intrusive rocks locally are capped by andesitic basalt flows and pyroclastic rocks (fig. __). Two basalt plugs intrude the Cottonwood granite at the deposit, and appear to be feeders for the extrusive rocks.

Aplite dikes cut the granitic rocks. The borders of the Cottonwood granite stock have an aplitic texture grading inward to coarse-grained, locally

porphyritic, rock. The Uncle Sam porphyry grades outward from a medium-grained rock having feldspar phenocrysts over an inch long to a finer-grained, inequigranular rock. In detail, the textural variations, in both intrusive rocks, is quite complex, and the above description is at best a gross generalization.

Structures. A northwest-trending shear zone occurs in the Cottonwood granite and wedge of metasedimentary rocks along the contact with the Uncle Sam porphyry. The zone is 1,000 feet wide and at least 10 miles long, the rocks within the zone having been broken up to a much greater degree than the surrounding rocks. Shearing apparently began before the intrusion of Uncle Sam quartz monzonite, and helped to control its emplacement, at least partially controlled the emplacement of the later Cottonwood pluton, and continued until after alteration and mineralization had taken place. The zone parallels the Cottonwood granite-Uncle Sam porphyry contact, and the regional structural pattern. Northwest of the intensively drilled area, the shear zone, mineralization, and alteration is hidden under a blanket of gravel; although two Molycorp holes were drilled here, only a single hole drilled by Geochemical Surveys penetrated this cover.

Metamorphism. The limestone and shale have been metamorphosed to marble, hornfels, and phyllite. The intensity of alteration varies irregularly. Some of the limestone beds have been altered to skarn. Bands of skarn (mainly epidote and garnet) are exposed in the wedge of metasediments between the two granitic stocks. Scheelite has not been noted in the skarn in the immediate vicinity of the deposit.

Alteration. Hydrothermal alteration has greatly affected the metasediments and Cottonwood granite in the shear zone. These rocks have been sericitized, silicified, and argillized. The more intensely altered area is at Poison Springs. Here, the most intense alteration, which extends for 3/4

of a mile along the shear zone, is delineated by steep, rapidly-eroding, treeless, yellow "badlands." Much of the intense look of the alteration at Poison Springs apparently is due to weathering rather than the original hydrothermal alteration; this is an area of abundant pyrite, and the highly acid and iron-rich conditions during weathering produced much of the argillization and distinctive yellow-staining. The intensity of alteration decreases both northwestward and southeastward along the shear zone.

Along the margins of the shear zone, where the alteration is the least intense, feldspars have been partially sericitized and argillized.

In the most intensely altered rock, the alteration is pervasive, clay sericite and/or quartz completely flooding the rock. Quartz "eyes" are the only remnants of the original granitic texture in much of this intensely altered rock. The silicification extends outward from numerous quartz veinlets that crisscross the altered area, forming a stockwork. These harder ribs are separated by softer sericitized and argillized rock. The distribution of the various types of alteration is irregular, and commonly overlaps.

In the less intensely altered rock, the alteration is not pervasive. The rock commonly is highly sericitized and silicified along quartz veinlets, but relatively unaltered rock remains away from the veinlets.

An interesting type of alteration, termed "aplite," is widespread but irregularly distributed through the altered area. This type alteration differs from the ordinary silicification in that the quartz "eyes" have been destroyed, the rock having a fine-grained, even, "aplite" texture. This "aplite" usually consists of feldspar, sericite, and quartz and forms resistant masses (often dike-like) which stand above the softer altered rock.

Mineralization. Molybdenite occurs in the altered Cottonwood granite and metasediments, along the shear zone. Small flakes and rosettes of molybdenite are disseminated through the altered rock and along the edges of the

quartz veinlets. Pyrite also is disseminated through the altered rock (where it appears to replace mafic minerals) and in the quartz veins, but apparently has no relation to the distribution of the molybdenite. The disseminated molybdenite is rare in clay alteration; where it occurs in a generally argillic zone it is intimately associated with a silicified or quartz-sericite subzone or with a quartz veinlet. The distribution is quite irregular and spotty. A geochemical survey of the distribution of molybdenum in soil (fig. __) showed anomalously high values along the shear zone with the highest values centered on the Cottonwood granite - metasediment contact which also is the center of the shear zone. Background values average 2 ppm Mo, values above 10 ppm can be considered anomalous, and values above 50 ppm especially significant. In areas that contained more than 50 ppm Mo the bedrock tended to contain roughly the same amount of molybdenum as the soil; only a narrow zone of 10-50 ppm rock occurs outward compared to the wider, diffused zone in the soil.

Copper minerals are almost completely absent in the molybdenum deposit, copper rarely exceeding several hundred parts per million. The copper in the soil forms an elongate aureole around the molybdenum anomaly, but the southwest limb (centered on the wedge of metasediments) contains much higher values (fig. __). Background ~~of~~ values average 20 ppm Cu, no samples showed less than 5 ppm. Tungsten and tin reportedly also are present in anomalously-high amounts. Zinc, like copper, is present peripheral to the molybdenum anomaly, with the highest concentrations in the metasediments, and in the most highly altered area (above Poison Springs). Because the background value is 0 (below detection limits), 1 ppm Zn is anomalous, yet concentrations of ~~ores~~ ores 500 ppm are common within the anomaly.

Secondary minerals are abundant at the surface, however molybdenite and pyrite also are quite common. Limonite, iron sulfate, jarosite, selenite, and other oxidation products are common. The water from Poison Spring and Roper

adit contain appreciable amounts of molybdenum. As is common in many molybdenite deposits, there has been relatively little leaching or secondary enrichment, and the grade of the molybdenum remains constant from the surface to a depth of at least 800 feet. Yellow ferrimolybdite (?) is present, but is not readily recognizable because of the other abundant yellow secondary minerals; it apparently ~~does~~ has not migrate any distance. Dark blue ilsemannite (?) is abundant on the dump of the Roper adit and along a fault zone in the most intensely altered part of the altered area. The mineral is presently being formed on the dump at points where water from the adit evaporates. At both localities, the "ilsemannite" apparently has migrated some distance before being deposited. The dark blue color changes to very pale blue then pinkish white with increasing humidity or when wet. The mineral is highly soluble and can exist only in arid climates. Actually, it probably occurs as Cucomungo as a whole family of minerals containing varying amounts of water and varying proportions of different valent molybdenums; some varieties may also contain sulfate.

Other Occurrences near Cucomungo

Many small shows of molybdenite are present in the area as offshoots of the main Cucomungo deposit~~s~~.

McBoyle Prospect. The McBoyle or Copper Canyon prospect is south of the Cucomungo deposit in Copper Canyon at the California-Nevada line in unsurveyed Sec. 16, T. 7 S., R. 39 E. One hundred feet above the canyon floor, molybdenite, pyrite, and minor quartz occur along a fault along the contact between "Uncle Sam" quartz monzonite porphyry and marble. In the canyon bottom, ilsemannite (?) and ferrimolybdite stain a 4-inch fault zone in the quartz monzonite.

Cucomungo Canyon. On the west side of Cucomungo Canyon in the SW 1/4

Sec. 5, T. 7 S., R. 39 E. near the California-Nevada line, molybdenite-bearing quartz veins in "Cottonwood" granite are exposed in a small pit.

GOLDPOINT MINING DISTRICT, ESMERALDA COUNTY

A large body of granite is exposed in the western part of Slate Ridge, smaller masses and dikes of the same rock being exposed elsewhere in the Ridge. The granite intrudes Cambrian shale, limestone, and quartzite. The sedimentary rocks are intensely metamorphosed near the granite but only slightly metamorphosed elsewhere. Aplite, pegmatite, quartz monzonite porphyry, and diorite porphyry dikes intrude the granite; rhyolite flows locally cap the other rocks. The granite is coarse-grained, and consists of orthoclase, quartz, biotite, and accessory zircon and magnetite.

Away from the granite, the sedimentary rocks are gently folded along northeast-trending axes, but near the stock dip steeply away from the granite stock with buckling and isoclinal folding being common. Normal faults cut the granite.

Stateline Mine.

The Stateline gold mine is on the south slope of the end of Slate Ridge in Sec. 27, T. 7 S., R. 41 E. Production has been small. A 10- to 14-foot vein, striking north-northwest and dipping 60° N., cuts Paleozoic dolomite forming a roof pendant in Jurassic (?) granite. The vein consists mainly of vuggy quartz and limonite carrying the gold values. A little wulfenite is scattered through the vein.

Bullfrog-George Prospect. The Bullfrog-George prospect is on the north flank of Slate Ridge on a domical hill near the Lida-Gold Mountain Road (This would put it roughly 2 miles south of Goldpoint.). According to Ball (1907, p. 192), the prospect is developed by several small cuts and pits. This occurrence could not be located with certainty.

At the prospect (Ball, 1907, p. 192-195), a 4- to 9-foot wide quartz vein, striking N. 70° W. and dipping vertically, cuts the granite and can be traced for about a quarter of a mile. Other quartz veins, which weather in relief and are traceable for long distances, are exposed in the surrounding hills; some of these veins contain feldspar and others grade into pegmatite dikes. The vein walls are gradational with the granite. Locally, the granite along the veins has been crushed and the fragments cemented by quartz. Elsewhere the vein quartz is crushed and recemented by "limonite" and chalcedony. The feldspar in the granite along the veins has been argillized.

Small pods and grains of pyrite and chalcopyrite, with less galena and chalcocite (?), are scattered through the veins. Vugs lined with quartz are common. In the oxidized portions of the veins, "limonite," malachite, cerussite, and azurite fill cracks and cavities. Free gold is present and

the main source of values. In the main vein, purple fluorite occurs in crevices in the quartz and as cubes up to 1/4-inch across lining vugs. Molybdenite occurs sporadically in small tablets and irregular masses in and between the quartz "individuals" of the main vein at the prospect. Bright-yellow needles and tufted aggregates of molybdite are present where the molybdenite is oxidized.

Redemption Mine. Ransome (1909) mentions that wulfenite occurs in the veins at the Redemption mine "about 1 1/2 miles due south of Hornsilver, on the other side ..... of Slate Ridge." (The old town of Hornsilver apparently was about 2 miles south of Goldpoint.) The mine is developed by several small adits and shallow winzes. The workings are on two parallel quartz veins, striking N. 40° W. and dipping nearly vertically, which cut limestone. In addition to sparse wulfenite, the veins contain galena, cerrusite, and cerargyrite (?).

On the crest of Slate Ridge, east of the Redemption mine and 3 1/2 miles south-southeast of Goldpoint (on the line between R. 41 1/2 E. and R. 42 E.), white, soft powellite occurs sporatically as psuedomorphs after flakes of molybdenite (?) in quartz veins cutting phyllite near the granite body. Aggregates of yellow ferrimolybdite also are scattered through the veins.

OTHER OCCURRENCES, ESMERALDA COUNTY

Black Horse Tungsten Mine

The Black Horse (Alice) tungsten mine is in Sec. 25, T. 2 N., R. 34 E., about 12 miles west of Coaldale and a short distance north of U. S. Highway 6. The workings consist of a 120-foot adit and numerous pits and trenches extending for about a thousand feet along the tactite zone. A small amount of tungsten has been produced from the workings.

Interbedded limestone, hornfels, quartzite, and meta-volcanic rocks are exposed in the mine area. Small crystals of scheelite are scattered through two northeast-trending tactite zones which apparently replace limestone beds.

A body of quartz monzonite is exposed several hundred feet to the north. Scheelite-quartz veins cut the tactite and country rock. Locally sporatic flakes of molybdenite and powellite occur with the scheelite.

Red Hill

Red Hill is a small hill immediately west of U. S. Highway 95 in Sec. 34, T. 4 N., R. 36 E. It is quite distinctive being much redder than the surrounding hills. This occurrence apparently is the same as that described as "near Redlick" by Sanford and Stone (1914, p. 120). It also has been known as Rock Hill although this name applies to the entire district. The only development has been 4 diamond drill holes: three holes (293, 306, and 785 feet deep) drilled by American Metal Climax during the winter of 1962-1963 in the gravel-covered flat northeast of the Hill and east of U. S. Highway 95; and a hole drilled into the Hill itself by Bear Creek Mining Co. in 1966.

An intrusive of quartz monzonite porphyry is exposed in Red Hill. The contact of this intrusive body with the surrounding rocks is everywhere covered by alluvium. The intrusive body has variously been considered to be mushroom-shaped, domal in shape, or domal but having its top displaced eastward by thrust-faulting. The two highway roadcuts in the east flank of the hill expose a stockworks of small, irregular quartz-pyrite veinlets in sericitized and silicified quartz monzonite. Molybdenite occurs along the margins of these veinlets. Smaller amounts of pyrite and rare chalcopyrite also are disseminated through the country rock. Limonite and ferrimolybdite fill pyrite (?) boxworks and coat fractures in the zone of oxidation. Younger, through-going, northwest-trending quartz-feldspar-fluorite veins cut the intrusive and surrounding rocks.

The three American Metal Climax holes penetrated alluvium and phyllite;

Figure ___. Geologic logs of the American Metal Climax drill holes at Red Hill showing rock types and copper and molybdenum content.

only in hole no. 3 was quartz monzonite encountered (see Fig. ___). No molybdenite was observed in the core; the phyllite contained 4-40 ppm Mo and 80-300 ppm Cu and the quartz monzonite 36-200 ppm Mo and 60-100 Cu. Some disseminated pyrite was encountered and in hole no. 1 a number of quartz veinlets containing sphalerite, scheelite, and pyrite were cut. The Bear Creek Mining Co. hole was entirely in the quartz monzonite and reportedly averaged 100 ppm Mo with no significant change in grade with depth.

Gilbert Mining District

The Gilbert mining district is in the vicinity of the ghost town of Gilbert which is 10 miles north of U. S. Highways 6 and 95 in the Monte Cristo Range of northern Esmeralda County.

In the district a "window" of pre-Tertiary rocks less than a mile square is surrounded by overlying Tertiary volcanic rock. Ordovician (?) limestone and minor interbedded shale and tuff intruded by quartz monzonite are exposed in the "window." The quartz monzonite is alaskitic, consisting essentially of quartz and feldspar.

Carrie Mine. The Carrie mine is in Sec. 26, T. 4 N., R. 38 E., 2 miles southeast of Gilbert. The deposit has been known since 1890, and has intermittently produced silver-lead ore. In 1925, the workings consisted of a 230-foot, inclined (50°) shaft with about a thousand feet of workings on three levels and considerable stoping on the upper levels plus some surface work. Reportedly, little work has been done since 1925.

Quartz veins occur in a 3- to 10-foot wide shear zone in limestone near the quartz monzonite intrusive. There has been movement along numerous surfaces in the shear zone; individual surfaces are wavy resulting in a braided pattern. The veins are a few inches to several feet in width. Iron and manganese oxides, copper carbonate, and bindheimite are common in the oxidized portions of the veins (Ferguson, 1927, p. 141). The wall rock is silicified and mineralized. On the 100-foot level, the veins consist of

quartz, some pyrite, galena, and tetrahedrite, and a little chalcopyrite and covellite. Stibnite occurs with galena, sphalerite, molybdenite, and scheelite on the 210-foot level (Lawrence, 1963, p. 65).

Hanson Prospect. Molybdenite reportedly also is found in the Hanson prospect which adjoins the Carrie mine.

Other Occurrences. The quartz monzonite intrusive at Gilbert has a fresh, unaltered center, but the margins of the intrusive is highly altered and contains widespread molybdenite - bearing quartz veinlets which extend out into the surrounding rocks which also are altered. Pyrite and minor chalcopyrite also are present in the veinlets. The veinlets show no preferred orientation.

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Lone Mountain

Molybdenite reportedly (Eng. & Min. Jour., vol. 76, p. 667, 1903) was found "on Lone Mountains, in Esmeralda County, about 14 miles from Tonopah ....." Molybdenite is found in NW 1/4 Sec. 13, T. 2 N., R. 40 E. in a low hill east of Lone Mountain --- it is not known whether this is the same occurrence as that mentioned in the Engineering and Mining Journal. The molybdenite and pyrite are disseminated in a quartz porphyry dike and in quartz veinlets cutting the dike (N. L. Archbold, personal communication). The dike is about 10 feet wide, is nearly vertical, trends east-west, and cuts metavolcanic rocks. Several shafts explore the mineralization.

Tonopah Divide Mine

The Tonopah Divide mine is 5 miles south of Tonopah in Sec. 27, T. 2 N., R. 42 E. in the Divide mining district. The mine is developed by a 580-foot shaft with workings on 5 levels. Several million dollars worth of silver and some gold were produced.

Crow Springs

Crow Springs is 25 airline miles northwest of Tonopah, at the northeast end of the Monte Cristo Range, in SE/4 T. 5 N., R. 39 E. Here, dikes and bodies of quartz monzonite intrude the Triassic Excelsior Formation (mostly quartzite in this area); these rocks are covered by Tertiary volcanic rocks (mostly rhyolite and quartz latite flows and pyroclastics) that have been tilted until they strike northwest and dip 30-60°SW; locally the volcanic rocks have been removed by erosion. The quartz monzonite is composed of large phenocrysts of orthoclase in a very coarse matrix of quartz, orthoclase, plagioclase, and hornblende; masses and dikes of late-phase aplite cut the main-stage intrusive rock. Premineral faults most commonly trend N. 45 W. and are vertical, or less commonly N. 60 E. with dips of 60-70° NW, or more rarely N-S with near vertical dips. Several sheared and brecciated areas cut the intrusive bodies; mineralization and intense alteration have been

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Figure __. Geologic map of the Crow Springs pluton.

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localized in these areas, and is almost entirely in the quartz monzonite.

The Copper Queen brecciated zone contains a stock work of quartz veins along shears that have the same general orientations as the premineral faults; the adjacent rock is silicified to "jasperoid"; oxidation has produced chalcopyrite boxworks and stains of "limonite," malachite, and azurite. The Star brecciated zone is characterized by argillic alteration along shears that strike N. 60° E. and dip 60°-70° NW. This alteration is more pervasive than the jasperoid alteration in the other area; turquoise, limonite, and chalcopyrite boxworks are present.

Surface samples from several areas, the largest being the Copper Queen zone, contain anomalously-high (more than 300 ppm) copper. Molybdenum anomalies (more than 30 ppm) are broader and less distinct; they cover both brecciated zones, as well as extensive areas with little alteration or evidence of mineralization.

93B
(to p. 92)

Drilling by Homestake revealed porphyry-copper type mineralization under the oxidized capping. Chalcopyrite is the main ore mineral, molybdenite is present in smaller amounts.

In the Divide district, silver-bearing veins, mostly trending north and dipping vertically, follow shear zones in the Fraction Rhyolite Breccia Member of the Miocene Siebert Formation (Knopf, 1921; Bonham, ____). Bodies of Oddie Rhyolite and Divide Andesite intrude the Fraction Breccia; Pliotene (?) latite flows cap these rock units. Numerous faults cut the rhyolite breccia. The faults form an extremely complex pattern, in this respect being a southward extension of the faulting at Tonopah.

The primary vein material is leanly mineralized fragments of the rhyolite breccia containing a small amount of fine, disseminated pyrite and minor thin veinlets of vuggy quartz. The rarity of quartz and silicification contrasts with the abundance of introduced silica in the Tonopah district. Supergene enrichment has resulted in the downward concentration of silver as "sooty" argentite, which subsequently has been almost entirely converted to cerargyrite. The cerargyrite occurs as masses along irregular seams of sericite.

Molybdenum minerals occur in one area of the Tonopah Divide mine, but have not been reported elsewhere in the mine or district. A considerable amount of bright yellow molybdite is present as aggregates of minute needles on the 165-foot level at the point where the discovery crosscut cuts the main lode. The molybdite disappears with depth, and at the corresponding position on the next lower level there is abundant powellite. The powellite is unusual in being present as distinct crystals -- crystals of powellite have only been reported from two or three other localities in the world. Pough (1937) states that those at the Tonopah Divide mine:

> occur in crusts, lining small vugs ..... and form continuous layers of firmly intergrown crystals. The component crystals are small, averaging about 1.5 mm. in breadth, although ..... the largest are as much as 5 mm. across. They differ greatly in habit and color. [They are] deep transparent brown to milky brown [as well as,] pale yellow-brown and almost completely transparent ..... Some are pyramidal, while others are thinly tabular, resembling wulfenite crystals of this habit.

Pough describes and illustrates their varied habit in some detail.

Goldfield Mining District

Columbia. Horton (1916, p. 87) states that molybdenite is found:

> At Columbia ..... with powellite, scheelite and kaolin.

Columbia is just north of the town of Goldfield in Secs. 35 and 36, T. 2 S., R. 42 E. The occurrence was not located.

Silver Pick Shaft. Molybdenite was noted (Searls, 1948, plate II) in alaskite encountered in the bottom of the 1300-foot Silver Pick shaft in the SE 1/4 Sec. 35, T. 2 S., R. 42 E. Alaskite also was encountered in the east end of the 1100-foot level. The alaskite intrudes Cambrian (?) shale; both are overlain unconformably by the Tertiary volcanic rocks of the district. Alaskite is exposed on the east face of the dump at the shaft collar; molybdenite occurs as isolated flakes and rosettes disseminated sparsely through the alaskite, and pyrite also is present as grains in thin quartz veinlets cutting the alaskite.

McNamara Mine

The McNamara lead-silver mine is on the north slope of Palmetto Mountain in the SW 1/4 of unsurveyed Sec. 6, T. 5 S., R. 40 E. The workings consist of a shaft, three adits, drifts along the vein, and several small stopes, totalling less than a thousand feet. Production has been small.

The deposit consists of small, irregular, oxidized orebodies in thin-bedded, impure Paleozoic limestones along a N. 60° W. - striking, steeply-northeast-dipping dike of alaskite. A large body of quartz monzonite crops out 700 feet to the south. The orebodies contain abundant limonite, barite, quartz, cerussite, locally abundant residual bunches of galena, and minor strains of malachite. Galena also is disseminated through the brecciated and silicified limestone adjacent to the ore shoots. Locally crystals of wulfenite form crusts on the galena.

Sylvania Mine

The Sylvania lead-silver mine is in the west-central part of Sec. 23, T. 6 S., R. 38 E. The mine is developed by several shafts and adits with several thousand feet of workings. Replacement bodies and quartz veins occur in limestone near a northwest-trending, north-dipping contact of Uncle Sam (?) quartz monzonite. The limestone appears to be present as a large roof pendant of the Inyo batholith; it, in general, strikes N. 55° W. and dips 65° NE, and locally is concordant with the intrusive body. The ore bodies appear to be mainly in two beds that are more dolomitic than the rest. The ore bodies are tabular, 50 to 200 feet long, and 3 to 20 feet thick (their down-dip dimensions are not clear). The primary ore consists principally of argentiferous galena, some sphalerite (which increases with depth), and pyrite. To a depth of 100 feet, in the zone of oxidation anglesite, cerrusite, silver chloride, smithsonite, and calamine are present. Molybdenite occurs in quartz veins and is abundant locally, and also probably is present in the ore bodies. Scheelite occurs in the skarn along the contact and in some of the quartz veins. Wulfenite is present in the oxidized ore.

EUREKA COUNTY

Mineral Hill Mining District

The Mineral Hill mining district is on the west flank of the Sulphur Springs (Pinyon) Range, mainly in Sec. 10, T. 26 N., R. 52 E., east-central Eureka County. The district was discovered in 1868. Over $2,500,000 worth of ore has been produced. Mining was continuous from 1868 to 1897, much of the production being in the early 1870's. There was some additional production from 1912 to 1919. Values were mostly in silver with some gold, copper, lead, and zinc. The workings are not extensive, reportedly totalling some 3,000 feet. They include principally open cuts, adits, and shallow stopes.

Emmons (1910, p. 96) described the geology; Vanderburg (1938, p. 51) adds information about the history of the district and metallurgical treatment of the ore.

In the Sulphur Springs Range, Paleozoic limestone rests on shale which in turn overlies Devonian quartzite. These rocks are folded into a syncline whose axis lies east of the ore deposits. The ore deposits are in gray, crystalline, dolomitic limestone dipping 45°-75° E. Three narrow dikes, striking east and dipping steeply south, cut the limestone. The dikes are highly altered, the least-altered rock being composed of quartz, sericite, calcite, and limonite.

The ore forms irregular replacement bodies in a breccia zone cutting the bedding of the limestone. The breccia zone trends north, and is 1/4 mile long and several hundred feet wide. The ore bodies are in the more intensely shattered parts of the zone. They commonly are 10 to 40 feet wide, extend from the surface to a depth of 120 feet, and commonly plunge 45° E. The underlying shale is cut by small barren quartz veins.

The mineralization occurs both as replacements and breccia-filling, and consists of quartz, silicified rock fragments, calcite, barite, silver chloride, argentite, tetrahedrite, galena, copper carbonates, sphalerite, pyromorphite, cerussite, polybasite, steffanite, silver bromide, pyrite, and iron and manganese oxides. Eissler (1898) mentions that molybdenite occurs in the ore.

The wall rock around the ore bodies has been highly silicified. Numerous faults, striking east and dipping about 60° N., cut both the ore mineralization and silicification.

Eureka Mining District

The Eureka mining district is in the north part of the Fish Creek Range, southwest of Eureka, in Ts. 18 and 19 N., Rs. 53 and 54 E., southern Eureka County. The district was discovered in 1864. In every year from 1871 through 1885 over a million dollars worth of ore was produced, more than 5 million dollars worth being mined in the peak year 1878. Total production has been more than $100,000,000; values were mainly lead, silver, and gold with some copper and minor zinc. There are numerous mines and extensive workings in the district.

Paleozoic limestone, shale, quartzite, and conglomerate crop out in the area. A quartz diorite plug of Cretaceous age is exposed in the district and is believed to be part of a larger concealed intrusive body. The rocks are intensely folded, and cut by thrust and high-angle faults. (Nolan, 1962).

The ore deposits are replacement chimneys, irregular bodies, veins, cavern linings, and bedded deposits associated with fissures in the limestone and dolomite. Oxidation extends to a depth of 1,200 feet. Caverns occur along the fissures, large caves being found above the principal ore bodies. Wherever the limestone and dolomite is mineralized it is crushed, fractured, and faulted. The ore below the zone of oxidation consists mainly of galena,

pyrite, arsenopyrite, and sphalerite. The oxidized ore consists principally of galena, cerussite, anglesite, mimetite, and wulfenite. The lead minerals contain more silver than gold; the iron minerals more gold by value than silver.

Wulfenite is relatively abundant and widespread in the oxidized ores of the Eureka district. Many very fine specimens have been found. Enough wulfenite was present to be of possible commercial importance according to Horton (1916, p. 89). Gianella (1941, p. 52) mentions that molybdenite occurs in the ore. It is present only in a few spots, and in very small amounts.

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Molybdenum also is present in appreciable amounts in the various types of slag ~~and other waste products~~ resulting from the smelting of the Eureka ores. A composite assay of the slags produced during 1878 by the Richmond furnaces shows 0.25 percent molybdenum. The speiss (mainly Fe As_2 formed during smelting, and containing important values which were difficult to recover) produced by the Richmond furnaces during the same year contained 2.31 percent molybdenum. Vanderburg (1938) considers that these values probably are representative of the over one million tons of slag and some one hundred thousand tons of speiss which once was present in the vicinity of Eureka. Much of these waste products have been reworked, used for road metal, etc.

Antelope Mine

The Antelope (Fish Creek Wells, Eather) mine is in the Fish Creek mining district near the west edge of the Fish Creek Range in Secs. 17 and 18, T. 17 N., R. 51 E. The deposit was discovered in 1870, and a few tons of shipping ore was produced during the next few years. In 1928, Judge Edgar Eather, Robert Kelly, and Ed Delaney, of Eureka, discovered molybdenite at the mine. In 1930, the deposit received a great deal of publicity in Nevada newspapers. Some development work was done but no ore was shipped.

The workings include a 350-foot adit, a 240-foot raise, and a number of shallow shafts, inclines, and other workings totaling about 1,000 feet (Vanderburg, 1938, p. 49). Much, if not all, of these workings apparently were made in the 1800's. Some stripping and trenching was done after the molybdenite discovery.

Shaly limestone, dipping steeply and trending north, is intruded on the north by granite porphyry. The limestone is contact-metamorphosed along the granite contact. This skarn zone is up to several hundred feet wide. Pyrrhotite, sphalerite, and molybdenite occur in the skarn. The pyrrhotite reportedly contains nickel.

Two fissure veins, ranging from 1 to 5 feet in width, cut the limestone. The vein material is mostly oxidized and contains silver, lead, and zinc. In the lower workings, bunches of pyrite, galena, and sphalerite are found in the veins. No molybdenite was noted in the veins.

Gibellini Manganese Mine

The Gibellini (Black Iron) manganese mine, is in the south-central part of Sec. 35, T. 16 N., R. 52 E., on the east flank of the Fish Creek Range. The mine is developed by open cuts, a 176-foot adit, a 305-foot inclined shaft, and over 1,200 feet of drifts and crosscuts made while mining manganese. The U. S. Bureau of Mines drilled several exploratory holes in 1946 (Binyon, 1948).

Several pipe-like bodies of psilomelane, pyrolusite, wad, and quartz occur in limestone. At the mine, a northwest-trending fault with ~~a~~ right-lateral movement extends across the Fish Creek Range. The ore contains appreciable zinc and nickel, and a little cobalt, copper, vanadium, and molybdenum. An assay of "representative" ore by the U. S. Bureau of Mines (Binyon, 1948) gave: 18.5% Mn, 3.7% Ba, 3.2% Zn, 3.0% Fe, 2.3% CaO, 1.7% Ni, 0.88% V_2O_5, 0.3% Co, 0.12% Cu, 0.11% Mo, and 41.6% Insol. A sample of "rich" ore assayed by the Nevada Mining Analytical Laboratory ran 43% Mn, 12% Ba, 5% Zn, 2% Fe, 2% Ni, 1.9% V_2O_3, 0.2% Co, 0.2% Cu, and 0.1% Mo.

The "spongy" nature of the ore, the shape of the orebodies, the rapid decrease in size of the deposit with depth, and the exotic metals in the ore, strongly suggest that the deposit is the eroded roots of a hot-spring, similar to the tungsten-rich hotsprings at Golconda and Sodaville, Nevada. Bedded deposits containing vanadium, zinc, and molybdenum (and possibly the other exotic metals) occur north and south of the manganese deposit (see below), and it is assumed that ascending hot waters remobilized the metals in these beds and redeposited them at and near the surface.

Gibellini Vanadium Deposit

North and south of the Gibellini manganese mine, vanadium and lessor amounts of zinc, molybdenum, nickel, and barium occur in Devonian (?) black shales and limestones of the western facies. The vanadium is present as red, yellow, and orange [illegible] The Gibellini claims extend for over a mile to the north of the manganese mine; the Bisoni claims are to the south-southeast ~~(see~~ in Nye County~~)~~. Values occur in a zone that is at least 10 miles long and locally is as much as 1/2-mile wide. At the Gibellini property the shale strikes N. 15° E. and dips 15° W.

A number of companies have explored the deposits. In 1967, Atlas Minerals drilled 20,000 feet of 200-foot holes on the Gibellini property; 18,000,000 tons of ore containing 0.3% V_2O_5 reportedly were found.

[illegible] & Palmer (BC)

OSGOOD MOUNTAINS, HUMBOLDT COUNTY

A large body of granodiorite is exposed in the northern part of the Osgood Mountains. The granodiorite intrudes limestone and interbedded shale of the Cambrian Preble Formation. Contact tungsten deposits occur in the limestones around the margins of the granodiorite; gold deposits occur along the Getchell fault that bounds the eastern edge of the mountains (Hotz

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Figure __. Generalized geologic map of the northern Osgood Mountains, showing the location of the various mines.

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and Willden, 1964). More than 600,000 units of WO_3 have been produced. Four tons of molybdenum were produced from the Tonopah mine in 1958 (see below). Petar (1932, p. 21) mentions that in 1917 "a little hand-picked molybdenite was mined near Osgood Mountain ... from a contact-metamorphic deposit."

The following mine descriptions briefly summarize the more detailed information in Hotz and Willden (1964), and adds additional details about the molybdenum mineralization.

Getchell Mine

The Getchell mine is mainly in Sec. 33, T. 39 N., R. 42 E. at the northeast edge of the Osgood Range. The workings consist of several open pits and extensive underground workings. Over 600,000 ounces of gold have been produced, mainly from the open pits. The Getchell epithermal gold deposit consists of gold associated with the arsenic sulfides, realgar and orpiment, in fractured rocks along the high-angle Getchell fault zone (Joraleman, 1951). Locally the gold-arsenic mineralization is superimposed on the contact tungsten deposit described below as the Tonopah mine.

Molybdenite is found in association with realgar, orpiment, marcasite, and stibnite in and near granodiorite dikes and sills that have penetrated the siliceous gold ore. Hotz and Willden (1964, p. 92) suggest that there may have been a long gap between the deposition of the tungsten and gold --- the tungsten being deposited in late Cretaceous time and the gold in the late Tertiary. This assumption is based mainly on the lead-alpha age of the granodiorite intrusive and the similarity of the gold mineralization to a widespread episode of mineralization of late Tertiary age in Nevada. If the above is true, it is not clear during which of the two periods the molybdenite was deposited --- the association with granodiorite dikes suggests the older, the association with realgar the younger. Possibly the two periods actually are parts of one continuous sequence of mineralization --- scheelite, then molybdenite and arsenic minerals, and finally gold and arsenic minerals --- accompanied by intermittent faulting.

no space left

Ilsemannite is locally common in the same general areas where the molybdenite occurs but is not found intimately associated with the molybdenite. The dark blue ilsemannite forms paint thin coatings along water courses in the shattered rock.

Tonopah Mine

The Tonopah mine is in the SW 1/4 sec. 33, T. 39 N., R. 42 E., and could be considered part of the Getchell mine. The mine is developed by several open pits 600 to 1,200 feet west of the open-pit workings of the Getchell mine, and underground workings accessible from an adit on the west wall of the South Extension pit. Open-pit mining began in 1950; underground operations began in 1953. Over 6,000 units of WO_3 have been produced.

In 1958, 19,058 pounds of molybdenite concentrates containing 45.4% Mo were produced and sold by Getchell Mine, Inc. (personal communication, W. H. Hisle). These apparently were flotation concentrates from ore mined in the underground workings of the Tonopah mine.

Scheelite occurs as small grains in pyroxene-garnet tactite in limestone of the Cambrian Preble Formation along the N. 50° W.-striking contact of the Osgood granodiorite stock (Hotz and Willden, p. 108). Pyrite, chalcopyrite, and molybdenite occur in quartz veins cutting the tactite and scheelite, and as disseminated grains and flakes in the tactite adjacent to the veins. Locally the tactite and granodiorite are impregnated with grey quartz.

Chase Prospect

At the Chase prospect, between the Tonopah and Riley Extension mines in NW 1/4 Sec. 4, T.38 N., R. 42 E., scheelite and powellite occur in a pit in sheared argillite along the Getchell fault.

Riley and Riley Extension Mines

The Riley (Reilly, Dernan) mine in the northern part of Sec. 9, T. 38 N., R. 42 E. and the Riley Extension mine in the southern part of Sec. 4, T. 38 N., R. 42 E. are in the same deposit but were mined separately because of differing ownership. The mines are developed by both open pit and underground workings. Over 170,000 units of WO_3 have been produced.

Scheelite occurs as small grains in tactite bodies in limestone of the Preble Formation along the contact with the granodiorite stock (Hotz and Willden, 1964, p. 106). Pyrite and chalcopyrite are locally abundant as individual grains and bunches in the tactite. Sphalerite and lessor galena also are fairly common but less plentiful than the pyrite and chalcopyrite. Molybdenite also is scattered sporatically through the tactite. Bismuthmite

also is present locally. Generally the sulfide minerals are concentrated in places where glassy gray quartz is abundant. This late quartz replaces the tactite and also is common in the granodiorite in contact with the tactite.

Granite Creek Mine

The Granite Creek mine is in the SW 1/4 Sec. 29, T. 38 N., R. 42 E., and was developed by extensive underground workings. Over 150,000 units of WO_3 have been produced.

Scheelite, and sporatic pyrite, chalcopyrite, and molybdenite, occur in tactite in northeast-striking, southeast-dipping limestones of the Preble Formation along the contact with the granodiorite stock (Schilling, 1962).

OTHER OCCURRENCES, HUMBOLDT COUNTY

Warm Springs Mining District

The Warm Springs mining district is on the west flank of the Pine Forest Range, 9 to 12 miles south-southwest of Denio. In the district a body of gneissic granodiorite intrudes Mesozoic (?) metasedimentary rocks. Gold-silver-bearing quartz veins occur in the granodiorite, and contact-tungsten deposits are found along its northern margin.

Defense Tungsten Mine. The Defense tungsten mine is at Cold Spring on the western slope of the Pine Forest Range, 1/2-mile south-southeast of the southeast corner of T. 46 N., R. 28 E. The mine is developed by several cuts and pits, and a 310-foot adit with an 80-foot raise and 110 feet of drifts. About 1,400 tons of ore averaging 1.0% WO_3 have been mined.

Granodiorite intrudes interbedded biotite schist, hornfels, and marble. Numerous aplite dikes cut the granodiorite and metasediments. Scheelite and minor molybdenite are scattered through small bodies of quartz-rich tactite where marble is in contact with the granodiorite, and in northeast-trending quartz veins that bound the tactite bodies.

Vicksburg Canyon. Molybdenite was noted in a 2- to 11-inch quartz vein in Vicksburg Canyon about 1/2 mile northeast of the Ashdown mine. The veins exposed in Vicksburg Canyon are part of the same system of veins exposed at the Ashdown mine (described below).

Ashdown Mine. The Ashdown mine is 12 airline miles south-southwest of Denio on the west edge of the Pine Forest Range. The mine is developed by a number of adits; underground workings total about 2 miles. Production has been less than 1/2 million dollars, mostly in gold.

Narrow, gently-dipping "pegmatitic" quartz veins cut the gneissic granodiorite. The veins generally strike northwest but are quite sinuous;

Figure ___ Geologic map and cross-section of the Ashdown mine - Vicksburg Canyon area.

at the surface the veins dip 20 to 40 degrees to the west but steepen markedly with depth. Locally K-feldspar and biotite are found in the veins; pyrite, chalcopyrite, and molybdenite also are present in small amounts. A composite sample of ten channel samples taken across the veins exposed in the underground workings ran 0.3 oz. Au, 0.3 oz. Ag, 0.005% Cu, and 0.002% Mo; the veins sampled varied from 2 to 10 feet in width. Molybdenum values are higher in the Vickburg Canyon portion of the veins.

Southern Pine Forest Range

The geology of the southern part of the Pine Forest Range is similar to that of the northern part of the Range. Much of the Range is granodiorite that intrudes Mesozoic (?) metasedimentary rocks. Quartz veins cut the intrusive and sediments, and contact deposits are found in the sediments around the intrusive.

Bartlett Creek. Two trenches on the southwest flank of Bartlett Peak in the NW 1/4 SW 1/4 Sec. 34, T. 42 N., R. 27 E. exposes scheelite, molybdenite, and powellite (?) in small bodies of epidote-rich tactite at the contact between Mesozoic (?) metasediments and granodiorite. The tactite replaces limy beds in a sequence of schist. Some tungsten ore has been produced. The mine has been variously called the Lincoln, Greenhorn, and Golden Scheelite.

Desert View Prospect. The Desert View (Leonard Creek) prospect reportedly is in Sec. 10, T. 42 N., R. 28 E., at an elevation of 6,900 feet on the west slope of a northeast-trending ridge. It is developed by an open-cut.

Quartz veins, striking northeast and dipping steeply north, cut porphyritic granodiorite. The veins are 20 to 115 feet long, and pinch and swell from several inches to 10 feet in width. Pyrite, chalcopyrite, and molybdenite occur in the wider parts of the vein. Malachite, azurite, and ferrimolybdite are present at the surface. The molybdenite is scattered through the veins as bunches and individual crystals up to 1/4 inches across (Kirkemo, Anderson, and Creasey, 1965).

Pass Creek. "Powellite" reportedly occurs in a quartz vein in the north-central part of Sec. 34, T. 44 N., R. 30 E. This occurrence reportedly is north of the road along Pass Creek, but could not be located during this study. The vein is in Mesozoic sedimentary rocks near a large body of granodiorite. It is quite possible that the mineral actually is molybdian scheelite rather than powellite.

Jupiter Prospect

The Jupiter (Bloody Run) prospect is northwest of Bloody Run Peak on the western flank of the southern Santa Rosa Range (Bloody Run Hills) in Sec. 11, T. 38 N., R. 37 E. The prospect is developed by a 30-foot inclined shaft, two short adits totalling about 120 feet, and several open cuts.

Small amounts of scheelite and molybdenite are present in a quartz vein in granodiorite. The vein is about a thousand feet long, a few inches to 8 feet wide, trends north-south, and is nearly vertical. Locally quartz stringers parallel the main vein. Kerr (1946, p. 17) mentions that the scheelite and molybdenite "are associated chiefly with sericitized or muscovite-bearing zones in the quartz."

Winnemucca Mining District

Horton (1916, p. 87) mentions that molybdenite occurs on Winnemucca Mountain "with quartz, chalcopyrite, and gypsum." This occurrence could not be located.

Molly Prospect

The Molly (Nevada Climax Mineral) prospect is at the south end of Edna Mountain in the SE 1/4 SE 1/4 Sec. 14, T. 34 N., R. 40 E. The prospect

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Figure ___. Geologic map and section of the Molly prospect.

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is developed by a 30-foot adit.

Thin parallel stringers of quartz follow sheeting planes in quartz monzonite along a contact with meta-andesite of the Pennsylvanian (?) Pumpernickel Formation. The sheeting gives the quartz monzonite a bedded appearance. The sheeting planes are 3 to 4 feet apart, strike northeast, and dip 20° NW. The veinlets are 3 to 4 feet apart, 1 1/2 inches thick, and do not extend into the andesite. Streaks of molybdenite, crusts of powellite, and grains of chalcopyrite, pyrite, and scheelite, are scattered through the veinlets. Samples of vein material ran 0.5 to 5.2% MoS_2, 0 to 2.6% WO_3, and 0.3 to 0.8% Cu.

A specimen of molybdenite from the "Golconda district" in the Mackay School of Mines Museum appears to be from this occurrence.

BATTLE MOUNTAIN RANGE, HUMBOLDT AND LANDER COUNTIES

The Battle Mountain Range is in southeasternmost Humboldt County and northern Lander County, northwest to southwest of the town of Battle Mountain. About $13 million worth at middle was produced prior to 1960, mainly from high-grade veins and bodies in Copper Canyon. Values were mostly copper, gold, silver, lead, and zinc. After 1961, Duval Corp. developed and presently is mining open-pit porphyry-copper-type deposits at Copper Canyon and Copper Basin.

The area is underlain by Paleozoic and Tertiary sedimentary and volcanic

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Figure ___. Generalized geologic map of Battle Mountain showing the locations of the various molybdenum occurrences.

rocks which have been intermittently folded and faulted by recurring orogeny that has continued until the present. Granitic rocks were intruded, mainly during mid(?)-Tertiary time. Contact metamorphism and hydrothermal alteration is widespread in the rocks surrounding the larger intrusive bodies. (Roberts and Arnold, 1965).

The principal types of deposits in the area are: (1) porphyry-copper deposits; (2) copper-gold veins and replacement bodies; (3) lead-zinc-silver veins and replacement bodies; gold-silver veins; and antimony veins. The ore deposits are arranged zonally around the larger intrusives. Copper, silver, and gold predominate in the inner zone; lead-zinc-silver in the middle zone; and antimony in the outer zone (Roberts and Arnold, 1965, and Sayers, R. W., Tippett, M. C., and Fields, E. D., 1968).

Molybdenite is present in and around all the granitic plutons, ~~for many~~ forming broad geochemical haloes. The molybdenite is most abundant in the margins of the intrusives and in the adjacent rocks. Exploration targets have been found and drilled at each of the plutons.

Copper Canyon Underground Mine

The Copper Canyon mine is in Sec. 27, T. 31 N., R. 44 E., along the east side of Copper Canyon in the southern part of the Battle Mountain Range. The mine consists of two shafts and workings on six principal levels, the deepest level being 700 feet, and numerous opencuts and pits. The mine has produced 48 thousand ounces of gold, 863 thousand ounces of silver, over 10 million pounds of copper, 6 million pounds of lead, and 3 million pounds of zinc; operation ceased in 1959. Duval Corporation's open-pit copper mine is immediately northeast of the shafts, and mines low-grade portions of the same ore deposit as the underground workings. The workings are principally in the Pennsylvanian Battle Formation which in the mine area consists of a lower conglomerate, middle hornfels, and an upper dense unit of quartzite and conglomerate. The formation dips steeply westward on the upper levels, but is vertical or overturned on the lower levels. A body of quartz monzonite crops out north of the mine and numerous dikes of quartz monzonite are exposed in the mine. The ore bodies occur between two parallel faults, striking north and dipping 65° W., some 800 feet apart. Another fault occurs between and roughly parallels the two bordering faults. Several other high-angle faults with random orientations extend between the bordering faults. Oxidized, enriched, and primary ore has been mined. The ore occurs in copper-gold and lead-zinc-silver replacement bodies.

The copper-gold replacement bodies range up to 400 feet long and 60 feet thick, and occurred in the lower chloritic conglomerate of the Battle Formation. The copper content decreased from 1 to 4% on the upper levels to less than 1/2% on the lower levels; the gold content averaged 1/10 ounce per ton and showed ~~in~~ no change with depth. The ore contained pyrite, chalcopyrite, arsenopyrite, pyrrhotite, and lessor galena, sphalerite, molybdenite, and scheelite, in a gangue of quartz, calcite, siderite, calcium and magnesium silicates, and barite. The molybdenite occurs mainly as small flakes in

narrow quartz veins and as fracture coatings ("paint"). Its distribution is erratic, but it apparently was most abundant on the 500-foot level; no attempt was made to recover it during mining. The molybdenite-quartz veins were deposited before the other sulfides.

Oxidized copper ore occurred near the surface and consisted of malachite, azurite, chrysocolla, abundant "limonite", and locally high gold values. Enriched ore was mainly along fault zones, and consisted mainly of chalcocite, cuprite, and covellite; enrichment rarely extended below the 300-foot level.

The one lead-zinc-silver orebody was on the 700-foot level in the middle hornfels unit, and averaged 2.5% lead, 1.5% zinc, and 3.0 ounces of silver per ton. The body was mainly galena, sphalerite, pyrrhotite, pyrite, and minor chalcopyrite. No molybdenite was noted in this orebody, but wulfenite is present in the oxidized portions of other lead-zinc-silver bodies in the Copper Canyon area.

Copper Canyon Porphyry-Copper Deposit

The Copper Canyon porphyry-copper deposit is in the SW 1/4 Sec. 22 and the NW 1/4 Sec. 27, T. 31 N., R. 43 E., along the ridge just north and northeast of the old Copper Canyon mine. This deposit presently is being mined as an open-pit; in 1966 ore reserves were estimated as 13,875,000 tons of sulfide ore averaging 0.8% copper, 0.47 ounces of silver per ton, and 0.025 ounces of gold per ton, and 25,403,000 tons of leachable secondary ore averaging 0.3% copper. No molybdenum is being produced.

The ore deposit (based on assay boundries) is 1,000-3,000 feet wide, 5,000 feet long, and 25-200 feet thick; overburden ranges from 0-200 feet in thickness. The primary mineralization consists mainly of pyrite, chalcopyrite, marcasite, and pyrrhotite which occur as fracture-filling with or without quartz, and as small disseminated grains. The mineralization is concentrated in the basal 150-foot conglomerate of the Battle Formation where the sulfides partially or completely replace the calcareous matrix of this

unit; hypogene mineralization also occurs in the clastic rocks of the Harmony and Pumpernickel Formations, and in the eastern part of the quartz monzonite stock which intrudes the sedimentary rocks. Minor amounts of arsenopyrite, molybdenite, sphalerite and galena occur in all the rock units, usually in quartz veinlets. Oxidation, leaching, and enrichment have taken place, and extends to a depth of more than 500 feet along fractures and faults (Sayers, Tippett, and Fields, 1968).

Buckingham Area

Molybdenite and pyrite occur in a fault zone at the Miss Nevada mine (Roberts and Arnold, 1965, p. 23) which is in a canyon half a mile northwest of Buckingham Camp (SW 1/4 Sec. 30, T. 32 N., R. 44 E) in the western part of Copper Basin. The workings are caved, and nothing further could be learned about this occurrence.

To the southeast of the mine, at Buckingham Camp quartz monzonite intrudes the Cambrian Harmony Formation. Molybdenite occurs sporadically along the contact of the intrusive body, and has excited considerable interest. Several companies have drilled here --- most recently the Union Pacific Railroad which began drilling in 1967. Erratic molybdenite values have been encountered along the contact, both in the intrusive and in the intruded rocks. The molybdenite occurs as paint along fractures and in quartz veinlets that form a stockwork. Abundant pyrite is present in the veinlets and as disseminated grains and masses in the wallrock. Deeper drilling (Union Pac.) reportedly has encountered higher-grade intervals of molybdenite-bearing rock.

Elder Creek Area

Molybdenite and chalcopyrite were encountered in a diamond drill hole in a bedrock "outlier" (located on the line between Sec. 36, T. 33 N., R. 43 E. and Sec. 1, T. 32 N., R. 43 E.) on the gravel-covered pediment extending out from the northeast flank of the Battle Mountain Range. The hole is in

granodiorite; mineralization reportedly was of the "porphyry-copper-type."

Just to the south, in the range front, similar granodiorite intrudes Pennslyvanian sandstones, arkoses, shales, and thin limestones of the Harmony Formation. The sedimentary rocks around the intrusives have been metamorphosed to hornfels and metaquartzite. Geochemical studies indicate that anomalously-high copper and molybdenum values are present in the bedrock, forming a halo centered on the intrusive outcrops. A gravity high also is centered on the intrusives and extends northeast onto the pediment (Erwin, 1967).

Considerable drilling has been done in this area in a search for porphyry-type deposits. Abundant disseminated pyrite has been encountered, but only sporatic chalcopyrite and molybdenite. The molybdenite usually occurs alone or with pyrite in quartz veinlets.

Trenton Canyon

A granodiorite stock at the head of Trenton Canyon, in Secs. 24 and 25, T. 32 N., R. 42 E., intrudes argillite, chert, and of the Pennsylvanian(?) Pumpernickel Formation. It is elongate northwest-southeast, and is approximately two miles long. Anomously high amounts of molybdenum occur along the contact, both in the intrusive and country. Utah Construction & Mining Co. has been drilling this area since 1966 in a search for porphyry-molybdenum type deposits. The molybdenite mineralization is similar to that found elsewhere in the Battle Mountain Range.

BATTLE MOUNTAIN-EUREKA MINERAL BELT, LANDER COUNTY

A distinct mineral belt extends from the Battle Mountain mining district southeastward through the Lewis, Hilltop, Bullion, Cortez, Antelope, Mt. Hope, and Eureka districts. The various districts occur in domal uplifts and are associated with granitic intrusive rocks. The molybdenum occurrences in the Battle Mountain "end" of the belt has been described in the proceeding section; the other Lander County occurrences will be described here.

Lewis Mining District

A specimen of molybdenite from "near Lewis" (Horton, 1916, p. 87) was in the California Bureau of Mines Museum. This occurrence could not be located during this study, but probably is in the ~~SW 1/4~~ SW/4 T. 30 N., R. 45 E.

Indian Creek

Molybdenite, powellite, scheelite, and quartz occur in hornfels near the Gray Eagle mine, in Sec. 13, T. 29 N., R. 46 E. (Schilling, 1962, p. 24). This occurrence was not located during this study.

Violet Shaft

The Violet shaft is "about 1 mile southwest of Tenabo," in Sec. 16(?), T. 28 N., R. 47 E. There is a caved adit in addition to the 208-foot shaft. "In the jointing of the country rocks [siliceous shale and chert] there are some small seams of molybdenite. Granite crops out nearby." (Emmons, 1910, p. 118).

Big Chief

The Big Chief prospect is in Sec. 36, T. 28 N., R. 46 E., a mile southwest of Goldacres; this occurrence is southwest of the main strand of the Battle Mountain-Eureka mineral belt. Some prospecting was done in the 1930's for copper, lead, and zinc; the presence of scheelite was first noted in the

1950's. There are a few pits and trenches on the property; there has been no production.

Small amounts of scheelite and powellite(?) occur in narrow bands of tactite in limestone along several quartz porphyry dikes. The limestone contains numerous northwest-trending calcite-quartz stringers that elsewhere in the area contain small amounts of scheelite, galena, and pyrite.

Cortez Mining District

Geochemical surveys in the Cortez area located several areas containing anomolously high amounts (over 100 ppm) of molybdenum (Erickson and others, 1961). During this study a molybdenum-rich double salt of phosphate-sulfate, tentatively identified as a member of the beudantite group, was found in the earthy yellow-brown material in a shear zone exposed in a short adit along the southwest side of Cortez Canyon. The mineral contained more than 1 percent each of Mo, Pb, and Ag.

AUSTIN AREA, LANDER COUNTY

New York Canyon

In the True Blue tunnel and other workings in New York Canyon in Sec. 33, T. 20 N., R. 44 E., several miles north of Austin, small quantities of molybdenite occur with pyrite, and some chalcopyrite, arsenopyrite, galena, sphalerite, tetrahedrite, and proustite, in quartz veins cutting Paleozoic quartzite adjacent to a stock of quartz monzonite (Ross, 1953, p. 56, 126, pl. 1).

Birch Creek

Several prospects along Birch Creek, in Secs. 25, 26, 35, and 36, T. 18 N., R. 44 E. expose molybdenite-bearing quartz veins in granodiorite. The principal vein so far exposed is up to 18 inches wide, strikes N. 50 W., and

dips 30° S.; it is developed by a 50-foot incline. Flakes of molybdenite up to three-fourths of an inch across are scattered through the white quartz, commonly associated with cream-white sericite(?) and small amounts of chalcopyrite which is largely altered to "limonite" and copper carbonates.

Linka and Conquest Tungsten Mines

The Linka (Garnetite) and Conquest (Peer) tungsten mines are in the west-central part of T. 17 N., R. 46 E., at Spencer Hot Springs near the north end of Big Smokey Valley. (The Linka mine has variously been considered to include all the workings, or only the southwestern workings.) The mines are developed by an open-pit, a 210-foot vertical shaft with some 1,000 feet of workings on the 150-foot level, and a 130-foot shaft inclined 45° south which is located 1,500 feet northeast of the main workings. The stopes in most cases have developed into glory holes.

From 1943 through 1951, 2,674 tons of ore averaging 0.72% WO_3 was produced. Considerable development was done in 1954 and 1955, and a flotation mill was built, and began milling tungsten ore late in 1955. The initial production rate was 300 tons a day; mining ceased in 1957.

A body of quartz monzonite intrudes thin-bedded limestones and hornfels. The sinuous contact trends north-northeast with the intrusive body being on the east side. A 20- to 30-foot ~~bed~~ band of the limestone along the contact has been contact-metamorphosed to garnet-quartz-epidote-calcite tactite. The tactite locally widens to up to 100 feet where dikes of the intrusive rock or small faults extend out into the limestone. Finely disseminated scheelite is scattered through the tactite. Flakes of molybdenite and grains of pyrite also are disseminated through the tactite, and are quite abundant locally. Powellite occurs as psuedomorphs replacing the molybdenite.

The possibility of mining this deposit as a low-grade open-pit operation --- recovering the molybdenite as a by-product --- should not be overlooked.

TEM PIUTE MINING DISTRICT, LINCOLN COUNTY

The Tem Piute (Tempiute) mining district is in the Timpahute Range in west-central Lincoln County. The tungsten deposits are at the north end of the Range in Secs. 25 and 26, T. 3 S., R. 56 E., Secs. 30 and 31, T. 3 S., R. 57 E., and Sec. 1, T. 4 S., R. 56 E.

History and Production

Silver has been mined intermittently in the district since 1868. Scheelite was discovered in 1916. In 1936 and 1937, Wesley Koyan and the Thiriot brothers, located the claims that became the Lincoln mine. A small mill was built at Black Rock, 15 miles west of the deposits, and about 250 tons of tungsten ore was treated.

In 1938, the Lincoln mine was leased to the Fegles Construction Co., who built a 40 ton mill; mining operations began in 1940; the capacity of the mill was increased to 75 tons in 1941. From 1940 through 1947, 434 tons of WO_3 was recovered from 81,872 tons of ore. Nearly all the ore was produced from the Lincoln mine, only a small amount coming from the Scofield mine of the North Tem Piute Mining and Development Co. which adjoins the Lincoln mine on the south.

The Atolia Mining Co. acquired the property in 1945, and after rehabititating the mine and mill, began production in 1947. In the early 1950's the Wah Chang Mining Corp. acquired the property, expanded the milling capacity to 1,000 tons per day, and actively worked the property until the fall of 1956. The total production is not known, but is substantial, and probably ranks second in the State. Since 1968 the Union Carbide Corp. has been drilling the tungsten deposits, reportedly with encouraging results.

The Lincoln mine is developed by a surface pit, 3 adits, an inclined shaft, and workings on 6 levels, that extend to a depth of 600 feet, and are connected by a number of raizes, winzes, and stopes. There are over 10,000

feet of horizontal workings and over 2,000 feet of vertical and inclined workings. The lowest adit is 2,700 feet long and connects with the 600-foot level. The workings of the Scofield mine, to the south, consist of shallow surface workings and an adit from which there has been some stoping. (Binyon, Holmes, and Johnson, 1950, contains maps of the workings.) The two mines are interconnected.

Geologic Setting

The Timpahute Range consists mainly of Paleozoic limestones, dolomites, shales, and sandstones, that strike north and dip steeply to the east (Wyant and Lemmon, 1951). Two quartz monzonite stocks intrude the sediments at approximately the contact between the Devonian and Carboniferous rocks.

Figure __. Geologic Map of the Tem Piute mining district (after Wyant and Lemmon, 1951).

Isotopic age determinations indicate that the intrusives are about 90 m.y. old (Krueger and Schilling, 1971). The beds dip radially away from the intrusion at angles ranging from 40° to 85° (Buseck, 1967). The intrusive bodies locally are concordant with the sediments. Near the stocks, numerous irregularly-oriented faults offset the sedimentary rocks a few feet.

Contact Metamorphism

Around the stocks the calcareous shale has been altered to hornfels, and the sandstone to quartzite. The limestone has been irregularly bleached and locally recrystallized up to 700 feet from the granite contact. Along the contact, the limestone has been changed to skarn. The contact between skarn and limestone is sharp, the gradational zone being less than 5 cm thick.

Along the west side of the southern stock, where both mines are located, part of the limestone is altered to thick bands of skarn paralleling bedding. Here a continuous band of skarn, 15 to 110 feet thick and some 6,000 feet long,

occurs directly against the quartz monzonite. A fairly continuous belt of platy hornfels, 25 to 110 feet thick adjoins the inner tactite band; lenses of skarn occur in hornfels. Large, less-continuous, masses of tactite are exposed west of the hornfels belt, extending up to 450 feet from the contact.

In contrast, although limestone is in contact around much of the northern stock, only a few small skarn lenses are exposed.

The skarn consists mainly of grossularite-andradite garnet and clinopyroxene (Busek, 1967), but also contains considerable quartz, actinolite, and calcite, as well as a host of other minerals some of which are locally abundant.

At the Lincoln mine, sulfide-rich skarn, 20 to 25 feet thick, occurs along the quartz monzonite contact, and is succeeded outward by up to 30 feet of skarn containing little or no sulfide minerals. The sulfide-rich skarn is a dense, hard rock consisting mainly of pyrite, pyrrhotite, quartz, up-to several percent marmatite (iron-rich sphalerite), rare chalcopyrite, and dark-colored skarn minerals. Sulfide-rich skarn also is present at the Scofield mine (Buseck, 1967). The sulfide-poor skarn consists of an inner pyroxene-garnet zone and an outer calcite-fluorite-chlorite zone. This, in turn, is succeeded by marbleized limestone containing some hornfels, and an outermost diopside garnet skarn. Within this zone either the diopside or garnet may predominate.

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Mineralization

Tungsten. Much of the skarn around the southern stock contains scheelite but only in a few limited areas has the grade been high enough to make mineable shoots (by the mining methods used in the past); several ore shoots have been mined at the Lincoln and Scofield mines. The lenses of skarn around the northern stock are too narrow (1-2 ft.) and discontinuous, and contain too little scheelite, to be economically significant. Scheelite mineralization in the skarn west of the main skarn bands is very erratic.

The scheelite is present as small, white to buff grains, fluorescing pale blue-white to pale yellow. It is more widespread than the sulfide minerals,

and is least abundant in the sulfide-rich skarn. The total amount of scheelite present is relatively uniform to at least a depth of 1,300 feet. Some of the richest tungsten ore bodies occur as coarse crystals of scheelite in masses of calcite-fluorite-sphalerite in marble remnants in the calcite-fluorite-chlorite skarn. Most of the production has been from one such calcite-fluorite-sphalerite mass, the Moody ore shoot of the Lincoln mine. The Moody ore shoot is 200 feet long along its strike, is 5 to 20 feet thick, and is known to extend at least 680 feet down its rake which is 62° NE. The shoot probably averages 1 percent WO_3, and 3 to 4 percent zinc.

Fine-grained scheelite also is common in the diopside-garnet skarn; this is known as the Grubstake ore zone.

Paragenetic relationships indicate that the scheelite was deposited after the skarn minerals had been formed but before the deposition of most of the sulfides. Only pyrite, and possibly molybdenite and sphalerite, show partial contemporaneity with the scheelite. The scheelite shows no particular spacial association with the sulfide minerals; though not mutually exclusive in their distribution, there is a definite tendency in this direction. The molybdian scheelite (that which fluoresces pale yellow) generally occurs where molybdenite is absent, molybdenum-free scheelite (blue-fluorescing) generally is found where molybdenite occurs with the scheelite.

Molybdenum Minerals

Molybdenite is widespread and locally abundant along the outer contact of the skarn in the diopside-garnet skarn. It also is present to a more limited extent along the skarn-quartz monzonite contact, and to a lesser extent in the rest of the skarn and in the intrusive body. The molybdenite occurs as isolated flakes and small bunches disseminated through the rock or in quartz veinlets. It does not show any particular spacial association with other minerals and specimens containing molybdenite most commonly do not contain

scheelite or sulfide minerals. Buseck (1967) mentions that "crystals [of molybdenite] have their folia oriented parallel to the contact and are twinned perpendicular to their length." The main dump at the Lincoln mine contains considerable molybdenite, many pieces of skarn containing over 5% Mo. The dump also contains considerable pyrite, pyrrhotite, and black high-iron sphalerite.

"Powellite" has been reported in the tungsten ore, but it is not clear whether this was powellite or molybdian (yellow-fluorescing) scheelite. Powellite does occur in a quartz lense in the skarn as psuedomorphs replacing molybdenite.

Sulfide and Associated Minerals. Pyrite is the most abundant and widespread sulfide in the skarn, but is most abundant in the sulfide-rich skarn zone; it usually occurs as discrete grains or small bunches. Pyrrhotite is common, but less widespread than the pyrite; it occurs as granular bodies and small grains associated with chalcopyrite and sphalerite, and is most abundant in the skarn nearest the contact (sulfide-rich skarn zone). Sphalerite also is relatively abundant; it is the black, iron-rich variety and most commonly occurs associated with fluorite as veinlets and individual grains in the outer part of the skarn (calcite-fluorite-chlorite skarn zone). Either chalcopyrite or pyrrhotite usually are present as inclusions in the sphalerite, chalcopyrite being more common near the intrusive and pyrrhotite away from the intrusive. Chalcopyrite is widespread but rare; it occurs as small veinlets and individual grains usually associated with other sulfide minerals. The bismuth minerals, bismuthinite, galenobismutite, cosalite, and native bismuth, and galena, occur with the sphalerite in calcite-fluoride-chlorite skarn. Magnetite is present with the iron sulfides in the skarn nearest the intrusive. Fluorite is locally abundant; it nearly always is closely associated with the sphalerite (Buseck, 1967).

Oxidation

The sulfide-rich skarn is oxidized to a limonite gossan to a depth of 20 or 30 feet. The adjoining skarn is oxidized to a much greater depth, gypsum and manganosiderite lining cavities. Solution cavities up to 5 feet across are present along marble-tactite contacts, and apparently were formed by surface water seeping down along the permeable contact.

Conclusions

This deposit appears to have considerable potential for tungsten mining particularly if less selective mining methods and higher-recovery milling techniques are used than those used in the past. And if the low-grade material also is mined, and all possible by-products (fluorite, sphalerite, copper, molybdenum, bismuth, ?) considered. Consideration should also be given to the possibility of mining non-tungsten ores, particularly adjacent to tungsten ores when economies in mining might make lower-grade material profitable to work.

OTHER OCCURRENCES, LINCOLN COUNTY

Patterson Mining District

"On the summit of the [Schell Creek] range at Swartz Canyon," which is 3 miles north of Patterson Pass in T. 9 N., R. 65 E., a few "scales" of molybdenite occur in a "rather strong" joint striking east and dipping steeply north in quartzite. A 300-foot adit has been driven on the structure. (Hill, 1916, p. 124).

This occurrence could not be located.

Manhattan Gap

A small, highly-altered quartz monzonite stock, west of the road through Manhattan (Stampede) Gap in SW 1/4 Sec. 9, T. 1 N., R. 66 E., is cut by molybdenite-bearing quartz veins. The area has been drilled by Bear Creek Mining Co. and the Humble Oil Co.

Totten Prospect

At the Totten propsect, powellite reportedly occurs as small pods along bedding planes in limestone. The prospect apparently is located near the intersection of Ts. 8 and 8 1/2 S., Rs. 68 and 69 E., but could not be located during this study.

LYON COUNTY

Devils Gate

"Molybdenite occurs in a small vein .... near Devils Gate" (Gianella, 1936, p. 92) in Sec. 8, T. 16 N., R. 21 E.

American Ravine

Molybdenite also occurs in quartz veins in American Ravine, southeast of Devils Gate (personal communication, Larry Beal).

Old Soldier Mine

Wulfenite reportedly occurs in several veins with tungsten and galena(?) at the Old Soldier mine on Churchill Butte in T. 17 N., R. 24 E. (Schilling, 1962). The mine consists of a 400-foot adit and considerable drifting made while mining gold and silver. The wulfenite occurrence could not be located during this study.

Benway Mining District

The Benway mining district is in Sec. 12, T. 14 N., R. 28 E. at the south end of a ridge extending southwest from the Desert Mountains, 10 miles north of Shurz and 1 mile west of U. S. Highway 95. Little is known of the history; production, if any, was small. The values are in copper, silver, and gold. The workings are very limited in extent.

Schrader, 1947, briefly described the geology of the district. Jurassic-Triassic limestone, shale, and sandstone have been intruded by Mesozoic(?) quartz monzonite having granodiorite and diorite phases. Aplite dikes cut the intrusive and sedimentary rocks, and apparently are a late phase differentiate of the quartz monzonite. All the older rocks are cut by Tertiary dikes and partially covered by Tertiary volcanic rocks.

Ten or more veins, striking N. 75° E. and dipping steeply south, are mostly in the quartz monzonite and limestone, and are associated with the limestone-quartz monzonite contact. The veins are up to 20 feet wide and up to a mile long. They consist mostly of crushed and altered rock, quartz, and

gouge, with argentite, chalcopyrite, and pyrite. Cerargyrite, malachite, hematite, "limonite," and manganese oxides are present in the oxidized portions of the vein. Molybdenite reportedly (Schrader, 1907) occurs in the veins.

Yerington Mining District

Sanford and Stone (1914, p. 120) mention that molybdenite occurs "in pegmatite .... in Yerington district." This occurrence could not be located.

It is interesting to note in this connection that the Yerington (Weed Heights) porphyry-copper deposit contains practically no molybdenite, in contrast to most porphyry-copper deposits which contain widespread molybdenite. Also in contrast to most porphyry-copper deposits the ore contains no appreciable gold or silver values, and quartz veinlets are relatively rare (Wilson, 1963).

McCoy Prospect

The McCoy (Flyboy) prospect is in the NE 1/4 Sec. 19, T. 11 N., R. 26 E. It is developed by a 170-foot adit made in a search for copper ore. 51 tons of copper ore containing some uranium reportedly was shipped in 1961.

Several persistent fractures and small shear zones in fresh quartz monzonite contain stains of secondary copper minerals, and a small amount of the secondary uranium minerals, tobernite, autunite, and phosphuranylite(?). The mineralization is concentrated in the quartz monzonite adjacent to aplite dikes. Blebs of chalcopyrite and flakes of molybdenite are disseminated sparsely in the quartz monzonite.

Cowboy Tungsten Mine

The Cowboy tungsten mine is in Sec. 22, T. 9 N., R. 25 E. on the west flank of the Pine Grove Hills. The mine consists of an adit with several hundred feet of workings, trenches, and pits made while exploring for and

mining tungsten. Ten tons of tungsten ore was shipped in 1941; 112 tons averaging 0.79% WO_3 was shipped in 1943. Some lead-silver ore was produced in 1963.

Fine-grained molybdian scheelite (yellow-fluorescing), accompanied by sparse rosettes of powellite psuedomorphic after molybdenite, occur in small, lenticular masses of skarn. The skarn is distributed irregularly in a 1 1/2-mile-long, arcuate, northwest-trending, northeast-dipping band of marble. Gneissic quartz diorite is in conformable yet intrusive contact with the northeast side of the marble layer. The marble and quartz diorite are intruded irregularly by quartz monzonite (Klepper, 1955).

W & P Mine

The W & P (Last Chance; Williams?) mine is in the SW 1/4 Sec. 34, T. 9 N., R. 26 E. in a canyon on the east flank of the Pine Grove Hills. Pyrite, chalcopyrite, molybdenite, and secondary copper minerals occur in narrow quartz veins in a 20-foot-wide, northeast-trending shear zone in quartz monzonite. Some molybdenite ore has been mined, and stockpiled at the property.

Molybdenite reportedly also occurs a mile to the northwest at what is known as the Big Moly claims.

Sweetwater

Michell (1945, p. 112) mentions that "at Sweetwater, Nevada .... a molybdenite deposit outcrops on the surface for 3,000 feet along a vertical dike of decomposed granite. Molybdenite and ferrimolybdite are disseminated in flakes, seams, and pockets." This apparently is in California, the only deposit in the area that fits this description is 5 miles southwest of Sweetwater (Ranch), on Green Creek just north of the ghost town of Star City in Sec. 31, T. 7 N., R. 25 E.

Gianella (1941, p. 52 and 80) mentions that at "Sweetwater" powellite and molybdenite occur in contact metamorphic deposits. This may refer to the Cowboy mine (above).

CALICO HILLS-BOVARD BELT, MINERAL COUNTY

The Rand and Bovard mines in the north end of the Gabbs Valley Range are along a northwest-trending fault zone, which is one of the strands of the Walker Lane fault zone. The particular fault strand that goes through the two mines is obscurred to the northwest by cover, however geophysical surveys and later drilling has located a string of ore deposits that are along the same trend (Lawrence and Wilson, 1966, and Lawrence and Redmond, 1967). Several of the deposits in this belt contain molybdenum minerals, and are described below.

Calico Hills Deposits

The Calico Hills deposits are six miles north of Schurz in the northern part of the Walker River Indian Reservation, east of U. S. Highway 95 in the SW 1/4, T. 14 N., R. 29 E. and NW 1/4, T. 15 N., R. 29 E.

The area is covered by Tertiary tuffs that are intruded by andesite plugs, dikes, and sills. Geophysical surveys outlined magnetic and induced polarization anomalies under this cover, and subsequent drilling located extensive mineralization at depths of over 1500 feet. The mineralization is over 2,000 feet. The drilling cut limestone, dolomite, calcareous shale, sandstone, and siltstone of the Luning Formation below the volcanic cover. These rocks are intruded by one or more intrusive bodies ranging in composition from quartz diorite to quartz monzonite. A contact, skarn zone on the south flank of these intrusives contains extensive and abundant replacement bodies of magnetite, pyrrhotite, pyrite, and chalcopyrite(?) that appears to have been deposited contemporaneously with the garnet, epidote, actinolite, calcite, and other skarn minerals. Later veinlets of magnetite, pyrrhotite, and pyrite cut the skarn and massive mineralization. Still later, late-phase quartz veinlets, containing pyrite, chalcopyrite, molybdenite, galena, and sphalerite, cut the earlier mineralization, skarn, and intrusive bodies. The copper mineralization appears to be most abundant peripheral to the magnetite bodies (Lawrence and Redmond, 1967).

Name Unknown

At a small prospect 2 miles south and slightly east of the SE corner of T. 13 N., R. 30 E., scheelite and a little molybdenite occur in garnet-rich skarn in limestone adjacent to a body of granodiorite(?).

Copper Mountain Mine

The Copper Mountain mine is in Sec. 2, T. 11 N., R. 31 E. and Sec. 35, T. 12 N., R. 31 E. on a spur extending northeast from the Gabbs Valley Range, 5 miles northwest of the Rand mine.

The mineral deposits at the Copper Mountain mine were discovered in 1906. Reportedly, (Schrader, 1947) over a million dollars worth of copper-gold-silver ore has been produced, mostly before 1920. There are over 6,000 feet of workings in the mine. The workings were developed through 3 shafts and several adits, and occur in an area 3,000 feet long, 1,000 feet wide, and 310 feet deep.

In the mine area, Mesozoic limestone has been intruded by irregular masses and dikes of quartz monzonite porphyry. Granodiorite dikes intruded the limestone, but apparently are older than the quartz monzonite; aplite dikes cut both the limestone and quartz monzonite. The granodiorite probably is an early stage differentiate and the aplite a late stage differentiate of the same magma from which the quartz monzonite was derived. Tertiary rhyolite, latite, and andesite extrusive rocks partially cover the other rocks.

The limestone in contact with the quartz monzonite porphyry has been garnetized, garnetiferous zones also extend out from the contact into the limestone. Other skarn minerals including epidote and actinolite are present in smaller amounts. The garnet is mainly grossularite with lesser andradite(?).

Irregular bodies of copper ore containing minor gold and silver values occur in the quartz monzonite porphyry, garnetized limestone, and unaltered limestone, most commonly on or associated with the quartz monzonite contact, but also in the quartz monzonite some distance from the contact. The quartz monzonite in which the copper mineralization occurs is intensely hydrothermally altered.

The primary mineralization consists chiefly of chalcopyrite, cupriferous pyrite, and chalcocite. In the quartz monzonite, the sulfide minerals most commonly occur as disseminated grains and streaks, forming a porphyry-type deposit. In the limestone, the sulfides commonly also occur as large masses. Quartz and calcite veinlets are common throughout the mineralized areas.

The oxidized mineralization consists of chalcopyrite, chalcocite, chrysocolla, malachite, cuprite, covellite, hematite, "limonite", and gypsum. Massive bodies of chalcocite and chalcopyrite are common at a depth of 60 to 100 feet and probably represent a zone of enrichment. (Schrader, 1947).

Molybdenite is present in the mineralized areas both in the garnetized limestone and in the hydrothermally-altered quartz monzonite. The molybdenite is especially abundant on the 300-foot level of the mine, being "so thickly disseminated in the hydrothermally altered quartz monzonite as to produce a salt-pepper pattern .... and it almost completely coats slickensided surfaces ...." (Schrader, 1947). The molybdenite is associated with chalcopyrite and chalcocite, and but by later quartz veins. Reportedly, at least some of what has been identified as molybdenite is actually graphite (personal communication, E. F. Lawrence), however molybdenite does occur in several of the dumps.

Rand Mine

The Rand (Nevada Rand) mine is near the north end of the Gabbs Valley Range, on the west slope of the Range in Sec. 29(?) or 30(?), T. 11 N., R. 32 E., 17 road-miles east of Nolan which is on a branch line of the Southern Pacific Railway.

The Rand mine was discovered in 1908. Most of the production was from 1919 to 1925. Estimates of total production vary greatly, but certainly have not been more than several hundred thousand dollars. The values were gold and silver. The mine has about 5,000 feet of workings on 6 levels, extending to a depth of 450 feet and laterally along the vein for about 400 feet.

The country rock at the mine is gray, tuffaceous, hornblende andesite, containing fragments of rhyolite and Jura-Triassic(?) slate. A faulted and brecciated zone, striking northwest and dipping vertically, cuts the andesite at the mine. The zone is 20 to 200 feet wide and about 5 miles long. It is the same zone as that exposed in the Bovard mine to the southeast.

Gold-silver veins occur, as flattish lens-like masses, up to 10 feet in width and 100 feet in extent, in the numerous, small, irregular faults and fractures making up the faulted and brecciated zone. In general, the veins parallel the trend of the zone, but are irregularly distributed within the zone. The walls of the veins, the ore shoots, and the zone itself are irregular. Gouge is common, especially along the walls. Oxidation extends below the deepest workings in the mine. The veins consist of silicified rock fragments and quartz containing hematite, free gold, electrum, cerargyrite, argentite, and a little tetrahedrite, calaverite(?), manganese oxide, pyrite, chalcopyrite, malachite, chrysocolla, tenorite, argentiferous cerussite, pyrargyrite, and polybasite. Wulfenite occurs in the veins as disseminated, white or yellowish, platy crystals. The high lead content of the ore apparently is mainly due to the presence of the wulfenite. Selenium also is present (Schrader, 1947).

The andesite in the faulted and sheeted zone is silicified, propylitized, and alunitized. This alteration is commonly more intense and abundant near veins and orebodies. Finely disseminated pyrite, and chlorite, epidote, calcite, quartz, chalcedony, and alunite were formed. The minerals, and thus the types of alteration, are distributed erratically.

Bovard Mine

The Bovard mine is near the north end of the Gabbs Valley Range, on the east slope of the Range, in Sec. 33, T. 11 N., R. 32 E., 1 1/2 miles east-southeast of the Rand mine. Development work has been done intermittently since 1908, but no ore has been produced.

At the mine, a series of Tertiary volcanic rocks overlie Jurassic-Triassic limestone. The volcanic series is about 2,000 feet thick, and consists, in descending order, mainly of andesite, rhyolite, and dacite, with the rhyolite being the most widespread and abundant. The Jurassic-Triassic limestone has been faulted and folded into an anticline that plunges northeast. A faulted and brecciated zone, striking northwest, cuts the volcanic series and limestone. This zone extends for about 5 miles to the northwest, and is the same zone that contains the veins at the Rand mine. The zone appear to "feather out" in the limestone at the southeastern edge of the Bovard property. (Schroder, 1947).

There are two, parallel, throughgoing veins at the Bovard mine, as well as several shorter veins and splits. The veins are in the northwest-trending faulted and brecciated zone, and consist mainly of brecciated quartz and silicified rock fragments stained and encrusted by iron and manganese oxides, and a little pyrite, chalcopyrite, and free gold.

Schrader (1947) states that the veins "locally are sparingly streaked bluish with molybdenite stains, as on the Hidden Treasure ground", and that "in the Hidden Treasure No. 4 shaft and the 120-foot tunnel to the northwest, the quartz .... is stained darkish and is freely parallel marked with streaks and stringers up to 1/10 inch wide of bluish-black ilesmannite ...".

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MINA-LUNING CLUSTER, MINERAL COUNTY

A number of molybdenum occurrences are clustered in the southeastern part of Mineral County in the vicinity of Luning and Mina. Undoubtedly a careful study of this area would turn up many more occurrences. This cluster is centered along the Walker Lane fault zone, and most of the deposits are associated with granitic intrusive rocks.

Sulphide(?) Prospect

There are a number of mine workings in Sec. 10, T. 7 N., R. 33 E., to which various names, Sulphide, Dawson Powellite(?), etc., have been given. Here, reportedly, quartz, pyrite, chalcopyrite, powellite, and scheelite occur along faults and bedding planes which generally parallel a granodiorite contact. The powellite and scheelite are most abundant along the walls of the quartz veins and in the adjacent skarn. The pyrite and chalcopyrite most commonly is disseminated in the intrusive and volcanic rocks.

New Boston Area

To the east of the Sulphide(?) prospect (above) in the NW 1/4 of T. 7 N., R. 34 E., there are a number of copper and tungsten (scheelite) deposits in limestones of the Triassic Luning Formation. Numerous granitic dikes, sills, and small bodies intrude the limestone and interbedded argillites. Quartz stockworks cut the intrusives, and to a lesser extent the

Figure __. Generalized geologic map of the New Boston area (modified from Nielson and Bear Creek Mining Co. maps)

sedimentary rocks and skarn. Chalcopyrite and secondary copper minerals occur in the stockwork veinlets and disseminated in the intrusives. Scheelite is disseminated in the skarn along the intrusive contacts, but also occurs to a limited extent in the veins. Molybdenite is present mainly along cracks in the limestone as "paint" without quartz or other sulfide minerals; molybdenite also is present in the veins and disseminated in the skarn.

Contact-tungsten deposits are more common in the western part of this area, and are rare in the eastern part. The molybdenite-"paint"-in-limestone occurrences are mainly in the eastern part of the area, but do overlap the areas of abundant tungsten mineralization. Bear Creek Mining drilled a

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Figure __. Log of Bear Creek Mining Co. Drill Hole NB-2.

640-foot hole in the NW/4, NE/4, NW/4 Sec. 15, T. 7 N., R. 34 E., encountering copper and molybdenum mineralization.

Santa Fe Mining District

The Santa Fe mining district, northeast of Luning, contains tungsten and copper deposits similar to those of the New Boston area (above), across the valley to the southwest. Not only are the deposits similar but the geologic environment --- small granitic intrusives in limestone and argillites --- also is similar. Molybdenite is present with the copper and tungsten, but whether molybdenite also occurs to any extent as "paint" in the limestone is not known.

The deposits of the Santa Fe district and those of the New Boston area, are separated by the northwest-trending Walker Lane fault-zone which in this area is thought (Nielsen, 1965) to have a total right-lateral, strike-slip displacement of 12 miles. Thus the deposits of the New Boston and Santa Fe areas may be offset portions of the same east-west belt of mineralization.

Douglas Prospect

At the Douglas prospect, south of Simon, in T. 8 N., R. 37 E., molybdenite reportedly occurs in a quartz vein. This occurrence could not be located.

Silver Dyke Mines

The Silver Dyke mines are along Silver Dyke Canyon in the eastern end of the Excelsior Mountains in Sec. 10(?), T. 5 N., R. 34 E., 5 miles southwest of Sodaville. The mine is accessible by a 6-mile dirt road extending west from U. S. Highway 3 miles south of Sodaville.

The tungsten deposits were discovered in 1915. By 1937 mining had virtually ceased, over $1,000,000 worth of scheelite concentrates having been produced making the area one of the more important tungsten producers in Nevada. From east to west along the productive area of the Silver•Dyke vein system, the workings are: the Beane mine, Wagner mine, Atkins shaft, Silver tunnel, and Goodale mine. The Noble mine is along a branch vein (see fig. __). In 1929, after the mines were acquired by the Nevada-Massachusetts Co., a crosscut-adit was driven 500 feet N. 26° E. to the Silver Dyke vein, and a drift extended some 4,000 feet along the vein connecting the Goodale, Wagner, and Beane mines.

Kerr (1936 and 1946) described the geology and mines in some detail, including geologic maps and sections of the workings and surface. Triassic(?) andesite flows, tuffs, and breccias, and interbedded hornfels and slate, have been intruded by diorite. Granodiorite and "albitized" dikes intruded the older rocks, and apparently are end phase intrusions from the same parent magma as the diorite. Tertiary andesite and rhyolite flows and tuff cap the older rocks east and west of the tungsten deposits. The granophyre dikes in the area apparently are related to the Tertiary volcanic activity.

Fig. __. Geologic Map of the Silver Dyke Tungsten Mines.

The diorite body crops out over an irregular elliptical area 1 1/2 miles long (east-west) by 1 mile wide (north-south). Much of the body has been invaded by albite and quartz. It also has been extensively kaolinitized, the kaolin occurring in funnel-shaped bodies with gradational contacts. The granodiorite dikes, a few inches to several feet wide, intrude joints in the diorite.

The diorite is jointed in a regular pattern. Near the Silver Dyke vein system the joints are nearly vertical and parallel the vein. Southward the

joints dip increasingly less steeply to the south. The joint pattern and the intrusion of the late phase granodiorite dikes along the joints suggest that the joints were formed in the margins of the domed top of the diorite body during or shortly after its emplacement.

The Silver Dyke vein system is in an east-west-trending fault (sheared and brecciated) zone 6 miles long and up to 600 feet wide. A number of small faults most of which strike east to northeast, offset the vein system short distances. The Triassic(?) meta-volcanic series in contact with the Silver Dyke vein system and diorite body is altered to quartz, albite, actinolite, chlorite, tourmaline, epidote, pyrite and magnetite, and cut by veinlets of quartz and albite.

The vein system consists of several, parallel, steeply-dipping to vertical fracture fillings forming a continuous zone extending over 6 miles east-west in the diorite and Triassic and Tertiary volcanic rocks. The vein

Fig. ___. Diagrammatic Section of the Silver Dyke Vein System.

system has several units that are remarkably persistent. Closely spaced, roughly parallel veinlets of quartz in the diorite form the footwall of the vein system; the veinlets making up this "ribbon" zone contain some scattered grains of scheelite.

Above the ribbon zone is the "replacement" zone which is up to 5 feet thick and consists of brecciated diorite, and less commonly volcanic rock, fragments recemented and partially replaced by quartz containing albite. Much of the scheelite in the vein system is in this zone. Where the breccia fragments are the more siliceous volcanic rocks, the zone is barren.

The hanging wall above the replacement zone is finely brecciated, unrecemented, barren quartz. Widely-spaced quartz veinlets are common in the hanging wall volcanic rocks and diorite.

The scheelite is concentrated in the portion of the vein system that is in contact with the diorite body. Although the tungsten-bearing solutions must have penetrated the volcanic series, very little scheelite was deposited in these rocks. Kerr (1946) points out that the diorite is the most calcareous rock in the vicinity of the tungsten deposits, and apparently furnished the calcium which combined with the tungstic acid to produce the scheelite. Rims of scheelite around partially replaced diorite fragments support this theory. The scheelite fluoresces pale yellow, due to the presence of molybdenum which averaged about 1/2 percent in the concentrates. No molybdenite or powellite has been reported.

Pine Tree Prospect

The Pine Tree prospect is in Sec. 18, T. 6 N., R. 36 E., in a canyon extending southeast from Dunlap Canyon, on the west flank of the Pilot Mountains. The prospect is developed by 2 adits totalling ~~less than a~~ several thousand feet. page 136 here

~~Pyrite, molybdenite, and sparse chalcopyrite occur in quartz veinlets and along fractures forming a stockwork in argillite and limestone that have been~~

Fig. __. Geologic Map of the Pine Tree Workings.

~~metamorphosed to hornfels and garnet-rich skarn. Secondary copper minerals malachite, azurite, chrysocolla, tenorite, and chalcanthite are present in breccia of a thrust fault that cuts through the deposit.~~

Gunmetal-Garnet Area

Several contact-tungsten deposits occur in the NW/4 T. 6 N., R. 37 E. on the east flank of the Pilot Mountains. At the Garnet (Victory) mine, scheelite-bearing garnet tactite up to 14 feet thick replaces limestone adjacent to several dikes and sills of granodiorite. The mine is developed by an open-pit, and inclined shaft in the pit bottom, and several other small

Pyrite, chalcopyrite, and molybdenite occur ~~in~~ with quartz m pods and stringers ~~veinlets and~~ along fractures and faults in and adjacent to a thrust fault. The copper mineralization, which includes secondary minerals, as well as chalcopyrite, is mainly in the thrust and overlying, brecciated limestone, dolomite, quartzite, and argillite of the Triassic Luning Formation, but also occurs to a more limited extent adjacent to the thrust in underlying conglomerates of the Jurassic Dunlap Formation. The molybdenite occurs scattered sporatically throughout the area of copper mineralization, probably averaging several hundredths of a percent; it apparently is most abundant in the outer, northern fringes of the copper body where it averages several tenths of a percent. Alaskite (aplite) has invaded the broken up rocks, contact-metasomatizing the limestone and dolomite to garnet-rich skarn and the argillite to hornfels. The alaskite in turn is broken by later movements on the thrust and has been mineralized. Paragenetic relationships suggest that the mineralization, metasomatism, and intrusion of the aplite are contemporaneous, and probably related to an underlying, bigger, parent intrusive.

pits. Some molybdenite is present as isolated flakes associated with pyrite and scheelite. Yellow-fluorescing scheelite or powellite(?) is present with the blue-white fluorescing scheelite. Ross (1961, Table 6.5 mentions that "pyrite and sphalerite also [are] found [here]."

At the Gunmetal (Lindsey) mine, less than a mile southwest of the Garnet mine, scheelite-bearing tactite replaces limestone adjacent to a body of granodiorite.

Kerr (1946, p. 175) mentions that "near Graham Springs" (which is in this same area) scheelite, and some argentiferous galena with associated wulfenite, occur in quartz veins or pipes in tactite layers in limestone that have been intruded by granodiorite and granodiorite porphyry. Scheelite also is disseminated through the tactite. This occurrence could not be located but seems to best fit the Garnet mine, although possibly it is at or near the Gunmetal mine.

Pilot Claims

The Pilot claims are in the SW/4 T. 6 N., R. 37 E., 3 miles south of the Gunmetal mine on the southwest flank of a spur of the Pilot Mountains. In this area argillites and interbedded pyroclastic units of the Triassic Excelsior Formation has been intruded by quartz monzonite which occurs as scattered outcrops, suggesting that a large body of quartz monzonite is present under the area. To the southwest the older rocks are covered by

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Fig. ___. Geologic Map of the Pilot Claims.

Tertiary volcanic rocks. Both the quartz monzonite, and the Excelsior Formation near the intrusives, are altered and mineralized. "Limonite," chrysocolla, malachite, azurite, and turquoise coat fractures. The quartz monzonite locally is strongly altered to clay and sericite. Geochemical surveys outlined several large areas that contained more than 500 ppm copper.

In recent years, this area has been drilled by Hecla Mining Co. and others. Reportedly porphyry-copper mineralization was encountered below the oxidized and leached surface croppings, however the grade was too low to make mining profitable. Chalcopyrite, pyrite, and some molybdenite were noted in core.

OTHER OCCURRENCES, MINERAL COUNTY

Broken Hill Mine

The Broken Hill mine lies between the Fairview and Paradise Ranges in Sec. 26(?), T. 14 N., R. 35 E. in the Broken Hill district, in the northeast corner of Mineral County. The mine was discovered in 1905. Most of the production was from 1913 to 1920, and totalled less than $100,000 with values mainly in silver and lead.

The mineralization at the Broken Hill mine is in andesite tuff and breccia, which are at least 350 feet thick. Andesite and basalt dikes and irregular bodies intrude the volcanic rocks. The volcanic rocks near the andesite dikes have been extensively hydrothermally altered. A large mass of granitic rocks crops out 2 miles southeast of the mine.

At least 6 silver-lead veins cut the andesite tuff breccia. Three veins strike N. 30° W. and dip steeply east or west. The other, "cross" veins strike east, or are intermediate between the two main trends. The veins are up to 9 feet wide, up to 2,000 feet long, and extend to a depth of at least 350 feet. The veins are oxidized to a depth of about 150 feet, and consist of gypsum, cerargyrite, cerussite, anglesite, "limonite," plumbojarosite, and jarosite. Primary sulfides --- argentiferous galena, some pyrite, chalcopyrite, and sphalerite, and rare molybdenite --- begin to appear in appreciable amounts at a depth of 120 feet, and increase in amount downward as the oxides decrease. Bismuth and cobalt reportedly occur in the primary ore. Proustite and pyrargyrite occur in both zones.

Nevada Scheelite Mine

The Nevada Scheelite (Leonard mine) is in Sec. 1, T. 13 N., R. 32 E. at the south end of the Sand Springs Range. It is developed by extensive underground workings made while mining tungsten ore. A hornblende-biotite granodiorite stock, isotopically dated as 85 m.y. old (Schilling, 1965), and

numerous small dikes and sills intrude steeply-dipping beds of Triassic(?) Excelsior(?) Formation. The Excelsior(?) Formation consists of metavolcanic and meta-sedimentary rocks containing an interbedded 500-foot limestone member. Tertiary volcanic rocks locally intrude and overlie the other rocks.

Tactite bodies averaging less than 15 feet, but locally up to 50 feet thick, occur in the limestone along the granodiorite contact. Hornfels has been formed where tuffaceous beds are in contact with the stock. Locally small fingers of tactite extend outward from the stock along bedding planes and dikes. The tactite consists of garnet, epidote, quartz, calcite, diopside, and wollastonite; scheelite and pyrite are locally abundant. Chalcopyrite and molybdenite are sporatically present through the tactite. The scheelite is molybdian, containing an average of 0.5% Mo. Mine run ore averages less than 0.6% Cu. No powellite has been reported. (Geehan and Trengove, 1950).

Laylander Prospect

The Laylander prospect is about a mile northwest of the Nevada Scheelite Mine. Here, a stock of granodiorite contains a porphyry-molybdenum-type mineralization. Molybdenite and pyrite occur in quartz veinlets that form a stockwork in altered granodiorite. The mineralization is not on the contact of the stock, but is scattered rather sporatically in areas away from the contact. Tertiary volcanic rocks locally cover the intrusive and mineralization. Drilling by Freeport in 1967 apparently encountered considerable "too-low-grade" mineralization.

Cory Canyon

Vanderburg (1937b, p. 46) states that "According to D. H. Donnelly of Hawthorne, molybdenite is present in Croy Canyon. In former years the deposit was prospected by several open-cuts. Molybdenite occurs on ground included in the Naval Ammunition Depot at Hawthorne." This occurrence is in the N/2 T. 7 N., R. 29 E., on the east flank of the Wassuk Range. Several small pits have been dug into the mineralization.

Alum Canyon

"Along Alum Canyon in the Wassuk Range south of Lucky Boy Pass, sporadic occurrences of porphyry-type mineralization (molybdenite and pyrite in quartz stockwork veinlets) are found in the margins of granodiorite bodies and in the intruded rocks, usually associated with areas of highly-altered rock that form yellow-brown badlands. The extent of the mineralization is not known. At the Lemr prospect, "south of Alum Canyon [NE/4 SE/4 Sec. 31 T. 7 N., R. 30 E.] there are, in or near the contact zone, bodies of sulfide ores with silver, gold, molybdenite, galena, pyrite, and chalcopyrite"(Hess and Larsen, 1921, p. 280). This deposit is associated with one of the several contact-tungsten deposits that occur in this part of the Wassuk Range. Roof pendants of Excelsior Limestone in the granodiorite have been partially contact-metasomatized to tactite. Scheelite is disseminated through the tactite, and also occurs in veins that cut the tactite. Ross (1961, Table 6.3) mentions that sphalerite also is present.

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Aurora Mining District

"Anomalously high values of molybdenum (up to 2 percent) have been found in quartz veins and limonite-coated fractures in a small area in the north part of the [Aurora] district .... It may be related to a Mesozoic(?) granite lying beneath the basal andesite of Aurora, which is approximately 1,000 feet thick" (U.S. Geological Survey, 1969, p. 19).

Pine Crow-Defender Prospects

There are a number of small contact-tungsten deposits in the SW/4 Sec. 9 and NE/4 Sec. 17, T. 4 N., R. 32 E. Here, molybdian scheelite occurs in tactite in limestone in contact with granodiorite (Ferguson, Muller, and Cathcart, 1954).

Mineral Jackpot Prospect

At the Mineral Jackpot prospect in Sec. 20, T. 4 N., R. 32 E., on the east flank of Bass Mountain at an elevation of 7,000 feet there are two small prospect pits exposing quartz veins. There are a number of these narrow (six inches or less wide) veins striking N. 80° W. and dipping vertically in the granodiorite intrusive; a few small "cross" veins trend at right angles to the other veins. Sporadic uranium minerals, pyrite, limonite, magnetite, molybdenite, tourmaline, and lepidolite(?) are present in the veins.

Queens

Kerr (1946, p. 176) states that " 3 miles northeast of Queens [in Sec. 11, T. 1 N., R. 32 E.?] ... quartzite, hornfels and marble are intruded by ... quartz diorite and granite porphyry. Scheelite occurs in sediments near the contact with diorite. The ore-bearing tactite is made up of garnet, epidote, calcite, idocrase, quartz, fluorite, molybdenite and scheelite."

TOQUIMA RANGE, NYE COUNTY

There are several molybdenum occurrences around the margins of the large composite granitic intrusive body in the southern part of the Toquima Range. Isotopic age dating indicates that the intrusive is about 80 m.y. old (Schilling, in press).

Round Mountain Mining District

Gianella (1941, p. 52) mentions that wulfenite occurs in the Round Mountain mining district. Nothing more is known about this occurrence.

Outlaw Mine

Dana (1932, p. 448) states the "benjaminite ... occurs with chalcopyrite, pyrite, covellite, muscovite, molybdenite, and fluorite, in quartz at the Outlaw Mine, 12 miles north of Manhattan, Nye Co., Nevada." This occurrence could not be located; the location given would place the mine at or near Round Mountain.

Spanish Belt Mining District

The Spanish Belt (Barcelona) mining district is 8 miles northwest of Belmont, in the SW/4 of T. 10 N., R. 45 E., and NW/4 of T. 9 N., R. 45 E. Molybdenite has been noted scattered sporatically over a large area. The occurrences are along the contact of the large, composite, granitic intrusive body exposed in this part of the Toquima Range. A ~~small body~~ cupola of porphyritic "late-stage" quartz monzonite is associated with the mineralization. The

Fig. __. Geologic Map of the Spanish Belt mining district.

granitic rocks intrude shales, argillites, sandstones, and limestones of the Ordovician Palmetto Formation.

Perkins Prospect. The Perkins prospect is a small open-cut at the west edge of the workings of the Barcelona mine. Massive to finely-disseminated molybdenite, pyrite, pyrrhotite, and lessor chalcopyrite occurs abundantly in hornfels near the main granite intrusive, and southwest of the small body of porphyritic quartz monzonite that appears to be a "late-stage" offshot of the main intrusive body. Isotopic age dating indicates that the two intrusive rocks were emplaced at about the same time (Krueger and Schilling, 1971 ~~in press~~). At the prospect, the rock contains up to 5% Mo, and the sulfide minerals make up some 50% of the rock.

Barcelona Mine. The Barcelona mine workings consist of an upper 2,100-foot adit, a lower 1,500-foot adit, extensive drifts and stopes connected to the surface by several raises and shafts (the shafts having been driven downward on the vein before the adits were driven). Both adits are caved. Over a half a million dollars worth of silver ore has been produced from the mine,

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Fig. ___. Map of the Barcelona mine.

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mostly from 1875 to 1890 and 1920 through 1922. Production was from the 2- to 10-foot northeast-trending, 45°-south-dipping San Pedro (Ernst) fissure vein which cuts the limestone, argillite, and granite. The vein contains banded quartz, calcite, cinnabar, silver minerals, tetrahedrite, stannite, and a little pyrite, galena, sphalerite, and chalcopyrite. The upper adit cuts the vein about 1,100 feet from the portal. At a distance of 1,250 feet from the portal tactite was encountered in limestone along the granite contact which here parallels the San Pedro vein. This was called the Barcelona "vein." The tactite consists mainly of garnet; molybdenite, and more rarely chalcopyrite and pyrite, are disseminated through the tactite (Hunt, 1936, chapter 1). On the dump of the lower adit molybdenite is disseminated through quartz monzonite porphyry; old maps seem to indicate that a dike-like prong of the "late-stage" porphyritic quartz monzonite was cut in

both adits, and it is assumed that the molybdenite-bearing quartz monzonite on the dump came from the margins of this "dike."

Kerr-McGee Drill Holes. In 1966, the Kerr-McGee Corp. drilled 3 diamond-drill holes in this area; one at the Perkins prospect and the other two short distances to the east (see fig. __). These holes explore the

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Fig. __. Variations in molybdenum and copper grade with depth in the Kerr-McGee drill holes.

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contact of the "late-stage" quartz monzonite. The holes encountered numerous quartz stockwork veinlets. Most of the veinlets contained molybdenite, many also contained pyrite and fluorite, and more rarely chalcopyrite. Several pegmatitic veinlets containing feldspar, in addition to quartz, molybdenite, and a little chalcopyrite, also were encountered. The same minerals found in the veinlets are also disseminated through the rock adjacent to the veinlets. The molybdenum and copper values are highest at the contact, but the mineralization extends at least several hundred feet into the quartz monzonite and the country rock. The country rock is shale, argillite, sandstone, and limestone, and their metamorphic equivalents slate, schist, quartzite, and marble and skarn.

Warren Prospect. The Warren or F&R prospect is 1/2 mile northeast of the Barcelona mine and the Perkins prospect, in SW/4 Sec. 32, T. 10 N., R. 45 E. Here a short adit explores a skarn zone in limestone along the northeast-trending, south-dipping contact of the main granite intrusive body. The skarn consists chiefly of garnet and epidote, and contains flakes of molybdenite, grains of pyrite, scheelite, and powellite, and rare films of ferrimolybdite in quartz veinlets and as disseminations.

Belmont Mining District

The Belmont mining district is on the east flank of the Toquima Range, east of the town of Belmont. The district was discovered in 1865. Mining was done mainly from 1866 to 1891 and 1920 to 1941. Over 59,000 tons of ore worth over $3,800,000 have been produced, the values being mainly silver.

Quartz veins and lenses occur in slate and limestone at and near a stock of granite. The intruded rocks locally have been altered to mica schist and jasperoid. Pyrite, sphalerite, and other sulfide minerals are disseminated through the quartz veins as bunches and grains. The primary silver mineral reportedly was stetefeldite --- a rare argentiferous antimony-copper-zinc sulfide --- but may have been a mixture of several minerals. However, much of the veins are oxidized, and the silver values are present mainly as silver chloride. Lincoln (1923, p. 160) stated that: "At the Belmont Big Four Mine, a quartz vein in granite is said to carry 2 per cent molybdenite besides silver and copper values." Horton (1916, p. 89) mentioned that a specimen of wulfenite from the Eldorado mine is in the Brush Collection at Yale University.

Manhattan Mining District

Ferguson (1924, p. 96) mentions that "molybdenite was found at one place, sparingly developed in silicated limestone." This occurrence could not be located.

HALL PROPERTY, NYE COUNTY

The Hall property is in the San Antone (Liberty) mining district on the west flank of the San Antonio Mountains in Sec. 5, T. 5 N., R. 42 E., one mile north of the Liberty mine and 22 road-miles north of Tonopah.

The deposits of the district reportedly were discovered in 1863. Small amounts of silver, gold, manganese, lead, and copper have been produced sporatically.

The Hall property was first prospected for silver; an inclined shaft was sunk and the first (110-foot) level driven. From 1935 to 1938, the U. S. Vanadium Corp. did some 3,500 feet of exploratory work deepening the shaft to 310 feet, and drove a 1,250-foot drift with crosscuts on the 280-foot level. In 1940, the Freeport Sulphur Co. sampled the workings. The U. S. Bureau of Mines did additional sampling in 1942 and 1943. Later in 1943, the Metals Reserve Co. sank two shafts, drove short crosscuts from the shafts, and drilled two diamond-drill holes. Anderson (1945) stated that the U. S. Bureau of Mines estimated reserves at 1,300,000 tons of ore containing 0.3 to 0.37 percent MoS_2. The workings now total over 4,400 feet, all the work since 1935 being done while exploring for molybdenum (see Anderson, 1945 for plans of the workings).

In 1956, the Anaconda Co. leased and optioned the property from Clarence H. Hall, W. C. Rigg, and Lee Hand; since then the company has under taken an extensive exploratory drilling program in a search for a large low-grade deposit. In 1966, Richard S. Newlin, Anaconda's vice president-engineering announced that exploration had revealed a low-grade orebody 4,000 feet in diameter with a known depth of 2,000 feet, that could be mined by open-pit methods at a probable rate of 10,000 to 12,000 tons per day. Newlin also reported that the 2,500 acre property had been purchased for $500,000, that 118,140 feet of core drilling had been done at a cost of $1,674,000, and that geologic and metallurgical studies and assaying had cost $663,000.

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The Anaconda Company is presently conducting a feasibility study on a mining property fifteen miles north of Tonopah, Nevada. The orebody is near the old Hall Mine which gives rise to the name of the Hall Project.

The orebody is a sulfide deposit, the target metal being copper and the main copper mineral is chalcocite. The ore reserves, although not completed, indicate quantities in excess of 40,000,000 tons with a grade range of 0.4 to 0.5%Cu. The host rock is a volcanic debris material intruded by a stock which was responsible for the mineralization. The quartz monzonite porphyry stock altered the volcanic sediments for a distance of up to 3000 feet from the intrusive. Strong quartz veining and disseminated pyrite mineralization are characteristic of this altered zone. In the stock, molybdenite is associated with intense quartz veining along the margins of the porphyry. The molybdenum was the first target metal at this property, but does not quite make "ore" at this time. It was good geological exploration that discovered the copper halo around the stock that developed the zone of mineralization which may eventually prove to be an orebody.

Mine planning has been difficult because the ore reserves and metallurgical results are not yet firm. It is anticipated

that mining will progress at a rate from 5-10M STPD of ore with a 1:1 stripping ratio, yielding a mine life of more than 15 years. The mining method would be open pit.

Metallurgical testing has proven that this mineralization cann economically be beneficiated by flotation, but does respond to a sulfuric acid leach. Moreover, it appears that the only viable leach method is a heap or dump type. Two main parameters are responsible for dictating the use of heap or dump leaching. The first is acid consumption and the second is recovery rate. Any total submergence treatment yields very high acid consumption - 10 to 20 lbs. per lb. Cu. At the present cost of sulfuric acid, it becomes evident that the economics are unfavorable for a vat leach. As stated before, the mineralization is sulfide and, consequently, the chemical and biological reactions take years. Here again, the heaps or dumps are better because they are stationary and can be treated over a long period of time. We are also anticipating a side benefit by heap or dump leaching and that is generation of sulfuric acid.

You will notice I have used the terms heap or dump when referring to the leach method. Throughout the industry each operation has a unique connotation of the words heap or dump when describing the pile of rocks they are treating. Rather than standardize the industry, I will give you our meanings

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of the words at the Hall project. A dump is any pile over 100,000 tons, built by constant dumping of trucks hauling run-of-mine material. A heap is a pile carefully built to avoid compaction and segregation. The material would be crushed and stacked to allow maximum ambient air induction. The size of the heap would be dependent on available room but nothing over 60 feet high. We are still investigating both methods although we would very much like to use heaps.

A possible recovery system is a liquid ion exchange with electrowinning. To those of you familiar with a Lix-electrowinning process, we are considering a system similar to Bagdad Copper Corporation and Rancher's Bluebird Mine. For those of you not familiar with this process, perhaps a brief explanation would be beneficial. The liquid ion exchange process, often referred to as solvent extraction, was developed by General Mills and is a chemical process dependent on an organic reagent called LIX. The reagent, normally LIX-64N, when mixed with a kerosine diluent will load copper from leach liquors. This loading action is called the extraction stage. The pregnant leach solutions enter the extraction stage where the copper is loaded on the organic, or we might say extracted from the aqueous feed solution, and the barren aqueous raffinate is ready to be returned to the dump.

147-D

The loaded organic is then transferred to the second phase called the stripping stage. Here the loaded organic comes in contact with a strong sulfuric acid solution which supplies numerous hydrogen ions. The loaded organic molecule in this environment gives up its copper ions and takes in hydrogen ions. As the copper ions are released, they are taken into solution and delivered to the tank house for electrowinning. The stripped organic is then recycled back to the extraction stage to be loaded again.

This process has several good characteristics as far as our property is concerned. First, there is clean tail water (raffinate) to be recycled to the leach heaps. This allows chemical reactions to take place as they should without complex additional iron compounds. Second, the process allows virtually no pollution. Everything is clean and recycled. Also, the entire operation requires less capital outlay than other available processes.

This outlines generally what Anaconda is investigating at the Hall Project. We are in the process of testing reactions, finalizing data, and completing the final feasibility report. We have no target date for start up at this time and will not have until all pilot plant test work is completed.

Thank you.

Previous Work. Kirkemo, Anderson, and Creasey (1956) described the geology of the deposit. Michell (1945) discusses the oxidation of the deposit. War Minerals Report 196 gives the results of the U. S. Bureau of Mines sampling, as well as other sampling. The following description is partially based on these publications.

The Rocks. A roughly circular stock of quartz monzonite, about 3,000 feet in diameter, has intruded Ordovician(?) mica schist and sericitic quartzite, and is overlain by Tertiary volcanic rocks which are predominately tuffs. Andesite dikes cut the schist, mineralization, and intrusive.

At the underground workings the schist is well foliated with muscovite the dominent mica, and biotite in lesser amounts; the foliation generally strikes northwest and dips steeply northeast and southwest. Elsewhere the schist includes fine-grained calcareous rock, hard slate, and quartzitic schist.

The quartz monzonite is variable in texture, ranging from fine-grained to porphyritic. The porphyritic variety consists of orthoclase and/or quartz phenocrysts in a medium-grained groundmass of orthoclase and quartz, some plagioclase, and rare muscovite and/or biotite. Biotite appears to have

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Fig. __. Geologic Map of the Hall molybdenum deposit.

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been much more abundant; it remains relatively more abundant in the mineralized areas. Pyrite commonly replaces the biotite. The quartz monzonite has been called alaskite, apparently due to the present rarity of the biotite.

In a general way, the intrusive body apparently resembles a cylinder whose axis dips gently east. The underground workings on the south flank of the intrusive reveal that the contact is irregular both in plan and section, but has a general dip of 80° NE (that is, the contact dips toward, instead of away from, the stock).

Structures. Numerous faults and fractures occur in the margins of the alaskite stock and in the rocks along the contact, forming a "halo" around the center of the stock. Quartz veins and masses fill many of the faults and fractures. Other faults displace the veins, quartz monzonite contact, and andesite dikes short distances. These faults have both flat and steep dips. Anderson and Cox (1935) state that: "there is no evidence contrary to the supposition that all of the faults are somewhat contemporaneous."

Silicification. Extensive quartz flooding, numerous quartz veins and masses, and fault gouge occur around the margins of the stock both in the quartz monzonite and intruded rocks, forming a "halo." Most of the veins are 1 to 4 inches wide. The "contacts" of the quartz halo are gradational, quartz veins being scattered sporadically outside the halo. Locally the quartz monzonite contains over 50 percent of the veins. (The areas mapped as part of the halo, in general, approached at least 30 percent quartz.) The orientation of the veins varies greatly; in some areas the orientation is completely random, in other areas the majority of the veins have one persistent attitude with the remainder having random strikes and dips. Persistent attitudes are more common in the eastern part of the stock. Numerous small masses of quartz accompany the veins, and are particularly abundant in the northern part of the stock; in this area the feldspar is largely altered to kaolin and sericite or replaced by quartz.

The quartz veins in the schist most commonly parallel foliation. The veins in the volcanic rocks are more randomly oriented and distributed more erratically, some ~~volume~~ volcanic rocks in contact with the stock being essentially free of veins.

There are several large masses of quartz in the alaskite and schist. These masses contain only minor remnents of the country rock, have gradational boundaries, and apparently have been formed by replacement.

Mineralization. Pyrite, molybdenite, and a little chalcopyrite occur in the quartz veins and pods throughout the halo of quartz flooding. The underground workings explore a concentration of veins in the schist and to a limited extent the quartz monzonite, along the southside of the intrusive. This "body" is richer in molybdenite than the rest of the halo; it is essentially tabular, 50 to 75 feet wide, and 1,500 feet long (northwest-southwest), and roughly parallels the contact and the schistocity.

The molybdenite occurs most commonly as small flakes and bunches in the quartz veins, less commonly as thin coatings ("paint") on fracture and fault surfaces, and more rarely along the margins of gouge-filled faults. In the quartz veins, the molybdenite is largely along the margins, in contrast to the pyrite which is distributed throughout the veins. Subsequent movement locally has smeared molybdenite along fault surfaces.

SUBJECT INDEX

Oxidation. Oxidation extends to a depth of 100 to 150 feet, locally extending much deeper along cracks. Usually the bottom of the oxidation zone is sharp. Yellowish-brown "limonite" fills cracks and stains surfaces. Malachite and azurite are present but rare. Some ferrimolybdite is intimately mixed with the limonite. The abundant "limonite" has obscured the color and other characteristics usually found in molybdenitic gossans. Powellite is erratically distributed through the mineralized area as psuedomorphs after molybdenite. An earthy blue molybdenum mineral (ilsemannite?) has been noted at a few spots.

In the oxidized zone 30 to 40 percent of the molybdenum is in the form of sulfide, in contrast to the over 85 percent sulfide content of the sulfide zone. The percentage of molybdenum shows no significant change from one zone to the other, indicating that the metal did not migrate readily. Some residual pyrite also remains in the oxidized zone. There is no enrichment (Michell, 1945).

OTHER OCCURRENCES, NYE COUNTY

Victory Tungsten Mine

The Victory tungsten mine, on the west edge of the Lodi Hills, north of Gabbs in Sec. 22, T. 13 N., R. 36 E. Production has been mainly from a contact deposit in limestone adjacent to granodiorite. North and west of the main working, scheelite, fluorite, and minor quartz are disseminated along cracks in crushed and feldspathized granodiorite --- what might be called a tungsten-porphyry deposit. A stockwork of quartz veinlets cut the scheelite-fluorite deposit (Humphrey and Wyatt, 1958).

Powellite reportedly occurs in small amounts in both deposits (as always when analyses of the "powellite" are not available, and the identification is based on its yellow fluorescence; this actually may be molybdenian scheelite).

El Capitan Tungsten Mine

The El Capitan (Ansonia) tungsten mine is in Sec. 26, T. 12 N., R. 36 E. on the south edge of the Lodi Hills, in a roof pendant(?) of dolomitic limestone in granodiorite.Scheelite occurs as closely spaced parallel layers up to 1 inch thick in elongate lenses of garnet-epidote tactite in limestone adjacent to the granodiorite. Small amounts of pyrite and molybdenite are disseminated erratically through the tactite.

Downeyville Mine

The Downeyville mine is in the Gabbs mining district on the west slope of the Paradise Range in Sec. 11, T. 12 N., R. 36 E. in the northwest corner of Nye County, 2.8 miles north-northeast of Gabbs.

Nearly all the production of the mine was from 1875 to 1887 when 2,357 tons of ore worth over $80,000 was mined. Values were mainly lead with some silver and zinc. Since then, the only production has come from the slag and oxidized ore dumps which have been shipped to various smelters. Mining has

been restricted to an area of 500 by 1,000 feet. There are numerous shallow shafts and "grass root" stopes. The main shaft is 380 feet deep. A small smelter was operated on the property.

The ore occurs in pipe-like areas of cross fracturing in Mesozoic limestone. These ore bodies commonly are 2 to 6 feet wide and in at least one case extend from near the surface to a depth of at least 380 feet.

Most of the ore is oxidized, and consists of porous "limonite" gossan containing cerussite and wulfenite. Pyrite, pyrrhotite, sphalerite, and galena are present in the deepest workings where the ore is unoxidized. The pyrite contains several 100 parts per million Mo.

Superior Prospect

At the Superior prospect in Wall Canyon in the Toiyabe Range in T. 10 N., R. 42 E., three shallow shafts and a 150-foot adit explore a vein in limestone which contains gouge, chalcocite, chalcopyrite, barite, and a little molybdenite.

Tonopah Mining District

Burgess (1911, p. 20) mentions that wulfenite occurs sparingly (as very thin, colorless to very pale-yellow, basal plates with diametral pyramids on the edges) in some of the veins in porous quartz masses associated with iodyrite, barite, and gypsum. Crystals of iodyrite commonly are perched on plates of wulfenite.

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Oak Spring Mining District

The Oak Spring mining district is in the vicinity of Oak Spring on the southeast flank of the Belted Range near the south end of the range in T. 8 S., R. 53 E., 115 miles northwest of Las Vegas. The district is in the Atomic Energy Commission's Nevada Proving Ground, and thus is not open for examination or exploitation. Some work was done in the district as early as 1905. The early activity was for gold, silver, copper, and "turquoise"; production was small. The tungsten deposits apparently were discovered in 1937. Some $6,000 worth of tungsten concentrates were shipped in 1940.

Morey Mining District

Molybdenite is present in quartz veins cutting welded rhyolite tuff at Morey Peak. The veins also contain pyrite, pyrrhotite, chalcopyrite, covellite, and tourmaline. The minerals probably also are present in these veins, as they are known to occur in other nearby quartz veins. The occurrence is in a caldera environment in which a jumble of fault blocks have been intruded by granitic rocks.

Two and a half miles south of Oak Springs, limestone and dolomite of the Ordovician Pogonip Group is intruded by the Climax composite stock of granodiorite and porphyritic quartz monzonite. The contact between the older granodiorite and the younger quartz monzonite is sharp. Numerous aplite and pegmatite dikes and sills cut the intrusive and surrounding rocks. Tertiary tuffs partly cover the other rocks (Houser and Poole, 1960).

Certain limestone beds near, but usually not on, the contact with the stock have been altered to garnet-epidote-quartz tactite. A little scheelite and pyrite, and rarely molybdenite, are disseminated through the tactite. Only at the Climax (Temply) mine on the northeast edge of the stock, and at the Garnetyte Lode mine on the southwest site or the the stock, is the scheelite sufficiently abundant to be ore.

A number of quartz veins fill fractures and "slips" in the stock and carbonate rocks. Pyrite, and lesser calcite, chalcopyrite, galena, and sphalerite, as well as their oxidation products are present in the veins. Scheelite is present in the veins as euhedral crystals; at the Crystal mine in the limestone on the southwest side of the stock, several hundred tons of tungsten ore have been mined from several high-grade shoots in the veins.

In some of the veins molybdenite is present with the scheelite. The molybdenite is largely altered to powellite. The powellite is dull gray, and occurs in platy masses (up to several centimeters across, and commonly bent and twisted in different directions) that are psuedomorphic after molybdenite. The amount of unaltered molybdenite varies from a considerable quantity to none at all. An analysis of this powellite gave only a trace of WO_3 (Schaller, 1911).

In 1962, as part of the "Hardhat" project, the Atomic Energy Commission, sunk a 780-foot shaft, with a 600-foot crosscut at its bottom, in the quartz monzonite. Three prominent joint sets are common throughout the stock, and are particularly well exposed in the crosscut: (1) a northwest-trending,

nearly vertical set; (2) a north-northeast-trending, nearly vertical set; and (3) a northeast, 20-35°NE-dipping set. In the crosscut molybdenite occurs disseminated as flakes, aggregates, and films ("paint") along the joints, in quartz veinlets and pegmatite dikelets along the joints, and in the wallrock adjacent to the fissure veins. Pyrite grains occur alone and with the molybdenite. Chalcopyrite is extremely rare.

EUGENE MOUNTAINS, PERSHING COUNTY

Nevada-Massachusetts Deposit

The Nevada-Massachusetts (Tungsten, Mill City) deposit is on the east flank of the Eugene Mountains in Secs. 26, 27, 34, and 35, T. 34 N., R. 34 E., in the north central part of Pershing County. The deposits are accessible by an 8-mile paved road extending north from Mill City on U. S. Highway 40-95.

The Tungsten deposits were discovered in 1917. In 1918, the Nevada-Humboldt Tungsten Mines Co. and the Pacific Tungsten Co. each built mills. In 1926, the present owners, the Nevada-Massachusetts Co. acquired the property of both companies. Production has been almost continuous from 1932 through 1957; the property has been one of the largest tungsten producers in the United States, both in terms of total and yearly production.

There are two tungsten-bearing zones. The western belt includes, from south to north, the Codd, Stank, Yellow Scheelite, Keyes, Hard Luck George, Springer, and Humboldt workings. In recent years, mining operations along this belt have been conducted as one unit through the Stank and Humboldt shafts. There are over 12 miles of underground workings, as well as extensive open pits.

A second belt 2,000 feet to the east, including the Sutton, North Sutton, Baker, and Uncle Sam workings, parallels the Stank-Humboldt belt. Workings along this eastern belt are less extensive. Kerr (1934) contains geologic maps of the workings.

The Rocks. Triassic phyllite and interbedded limestone, generally striking N. 0°-20° E. and dipping 70° W. east of the Stank thrust fault and 65° E. west of the fault, are intruded by granodiorite and later aplite and pegmatite dikes and quartz veins. Dikes of hornblende andesite cut the other rocks.

A body of granodiorite underlies the area, croping out mainly north and east of the tungsten deposits, but also is exposed to a more limited extent elsewhere. Dikes and small masses of granodiorite, and end-stage aplite and

Fig. __. Geologic Map of the Nevada-Massachusetts tungsten deposits.

pegmatite, extend out from the stock. Mining operations have shown that the shape of the stock is irregular, and that the sedimentary cover is much thicker than the outcrop pattern would suggest. The granite contact commonly dips steeply in the vicinity of the tungsten deposits. Isotopic age dating indicates that the granodiorite is about 90 m.y. old (Krueger & Schilling, ~~in press~~ 1971).

Structures. The post-depositional Stank thrust fault, which cuts diagonally northwest across the south part of the area, is the most prominent structural feature. Other smaller faults cut and offset the rocks. Many of these were formed during the intrusion of the granodiorite, before the deposition of the tungsten. Most of the other faults have been formed by regional deformation after the tungsten had been deposited.

Contact Metamorphism. Along the granodiorite contact, the phyllites have been contact-metamorphosed to olive-green to light gray, hard, hornfels, consisting of a fine-grained mosaic of quartz and actinolite or locally biotite, with minor cordierite, apatite, zircon, rutile, and pyrite. Black bands in the hornfels consist of hornblende crystals in quartz.

The limestone beds are altered to tactite consisting of garnet (andradite and grossularite), quartz, calcite, and epidote, and varying amounts of idocrase, actinolite, tremolite, and wollastonite. Late quartz veins fill tension fractures in the tactite and adjoining hornfels.

Tungsten Mineralization. Scheelite occurs as white, anhedral to subhedral crystals, from less than a millimeter to several centimeters in diameter, disseminated in varying amounts through the tactite. Locally it is abundant enough to form high-grade ore bodies. The most productive area has been west

of the granodiorite stock where several, north-trending, 1- to 8-foot beds

Fig. __. Geologic cross-section through Stank Hill.

of limestone, separated by up to 200 feet of hornfels, form the Stank-Humboldt belt. A second less-productive zone consisting of two, 3- to 5-foot limestone beds 30 to 50 feet apart, occurs east of the Stank-Humboldt belt, and is known as the Sutton belt. Kerr (1946, p. 187) states that: "Locally, over a few feet, the ore distribution ... is often extremely erratic. Where stratum is not completely replaced [tactized] the ore may have accumulated along the footwall ... while elsewhere ore may occur along the hanging wall. Even ... in the vicinity of high-grade scheelite deposition, blocks of unreplaced limestone as much as 20 feet across are found." It is not clear how much scheelite actually is present in the hornfels. Some scheelite also is present in quartz veins which fill tension fractures in the tactite and extend up to several hundred feet out into the surrounding hornfels. Most of the scheelite in the tactite and veins fluoresces bluish-white; yellow-fluorescing scheelite has been reported in a few small areas.

Sulfide Mineralization. Small cubes of pyrite are disseminated through quartz and the other contact-metamorphic minerals making up the tactite; pyrite also is present in the late-stage, quartz veins. Traces of pyrrhotite, chalcopyrite, stibnite, and bismuthinite(?) are present, mainly in the veins. Molybdenite is more abundant than the other sulfides; it occurs disseminated in the tactite, and alone or with other sulfide minerals and/or quartz filling fractures in the garnet, epidote, and scheelite. Kerr (1934, p. 30) states that "molybdenite is found in a small concentration a few feet long and about six inches in width occurring on the 300 level on the Stank mine just north of the shaft ...[and] is widely distributed in small amounts in the lower

levels of both the Stank and the Humboldt ore bodies." On the 300 level in the Stank mine, the molybdenite is associated with very dark brown andradite(?) garnet which is uncommon elsewhere in the deposit.

Iron Forge Prospect

The Iron Forge (Forge) prospect is in the SW 1/4 Sec. 2, T. 33 N., R. 34 E. An adit and several pits were made while exploring for tungsten. Here a small area of granodiorite is exposed at the edge of the gravel-covered

Fig. ____. Geologic Map of the Iron Forge Prospect showing its relation to the Nevada-Massachusetts deposits.

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Humboldt Valley. Scheelite is disseminated through tactite along the north (exposed) edge of the granodiorite; the contact-metasomatized rock is in the same limestone beds that contain scheelite at the Nevada-Massachusetts mine. Molybdenite is present, with pyrite and rare chalcopyrite, as small disseminated flakes in the tactite, and in quartz veins cutting the tactite. Cosalite (a lead-bismuth sulfosalt) is present locally in the quartz veins (personal communication, H. F. Bonham).

The topography in this area suggests that there is no frontal fault along the edge of the Eugene Range, and that a pediment surface may be present at shallow depths under the valley-fill gravels. Thus there is a possibility that much more extensive mineralization exists under the gravel cover.

Fifty-Six Mine

The Fifty-Six (56) mine is at the south end of the Eugene Mountains in Sec. 27, T. 33 N., R. 33 E. on the shore of the Rye Patch Reservoir just north of the Imlay-Majuba Hill road, 6 miles west of Imlay. The Fifty-Six mine was located in 1861. Some copper ore was shipped in 1917. The mine is developed by a shaft and shallow workings (now caved). "High-grade" molybdenite reportedly (Reno Evening Gazette, December 20, 1943 and January 5, 1944) was discovered in 1943 by Harvey Mudd and associates, of Los Angeles, while drilling a "deep" hole. The presence of molybdenite apparently has not been

mentioned except in newspaper accounts. The workings are in a granodiorite intrusive body; granodiorite on the dump is stained by malachite, and contains a little pyrite that has been almost entirely oxidized to "limonite." Reportedly, molybdenite was not noted in the workings, but only in the drill hole.

OTHER OCCURRENCES, PERSHING COUNTY

Rose Creek Mine

The Rose Creek mine is on the northern end of the East Humboldt Range in Sec. 6, T. 34 N., R. 37 E., just south of the Humboldt-Pershing County line. The mine was first located for copper and gold, however no exploratory work was done until 1936 when tungsten was discovered. Shallow trenches explore the outcrop of the tungsten-bearing tactite layer for over 500 feet along its strike. The underground workings include a 400-foot adit-drift, an inclined winze which follows the ore downdip, 3 raises, and a crosscut.

Triassic dolomite, limestone, argillite, and quartzite are intruded by bodies of granite, granodiorite, and diorite, and dikes of diorite porphyry, lamprophyre, and diabase (see Roberts, 1943, plate 1, for a geologic map of the mine area). Small pegmatite and aplite dikes fill fractures in the intrusive bodies. The lamprophyre and diabase dikes cut and displace the tungsten-bearing tactite. The lamprophyre dikes contain some scheelite, suggesting that they were emplaced while tungsten was still being deposited. In contrast, the diabase dikes apparently were intruded after the tungsten metallization stopped.

The rocks in the vicinity of the mine are complexly folded and faulted. A thrust fault cuts the rocks, and there are numerous normal faults, a number of which offset the thrust fault. The normal faults can be divided into two groups: (1) an older system generally striking north to northeast; and (2) a younger system generally striking northwest. A well-developed system of joints, striking N. 10°-20° W. and dipping steeply southwest, occur in the granite bodies east and southeast of the mine.

The rocks adjacent to the granitic bodies have been contact-metamorphosed. The intruded rocks commonly are feldspathized for a few feet outward from the bodies; recrystallization has taken place up to a mile from the outcrops of

Majuba Hills

At Majuba Hill, 20 miles west of Mill City, in the Trinity Range, molybdenite occurs in a "lower" adit presently (1970) being driven to explore the downward extension of the copper-tin bearing veins (personal communication, D. L. Evans). This deposit has been described by Smith and Gianella (1942).

the bodies. The limestone and quartzite have not been affected greatly; both have become coarser-grained, but there has been little change in their mineral composition. The argillite was altered to hornfels over an extensive area. The calcareous argillite beds for hundreds of feet away from the contact were changed completely to tactite consisting of abundant diopside, actinolite, feldspar, and quartz, and minor apatite and sphene. The relative amounts and distribution of the minerals varies irregularly.

The tungsten-bearing tactite "bed" at the mine is up to 4 feet thick (averaging about 2 feet), strikes generally east, and dips 30°-45° N. In detail, the tactite thins and thickens, and has many minor flexures, the tactite paralleling the bedding of the enclosing argillite. Several lamprophyre and diabase dikes and normal faults cut and offset the tactite and granite short distances (see Roberts, 1943, plate 3 for geologic map of the mine workings).

The tactite in the workings averages 1.5 percent WO_3. The scheelite occurs as grains up to 1/2 inch long, most commonly disseminated through the tactite, but locally distributed along cracks or in small quartz veinlets. There are two varieties of scheelite: one variety fluoresces bluish-white and contains about 0.05 percent molybdenum; the other fluoresces light yellow and contains about 1.8 percent molybdenum. Some crystals of scheelite consist of one or the other variety, but most commonly both are irregularly intergrown in the same crystal. Some grains have a core of one variety enclosed in a shell of the other; the yellow-fluorescing variety more commonly forms the cores. Pyrite and chalcopyrite, and more rarely sphalerite, arsenopyrite, and molybdenite occur in small quartz veins and disseminations throughout the tactite and adjacent rock. The tungsten ore reportedly contains as much as 1.5 percent copper and 0.14 ounces of gold per ton.

Stormy Day Tungsten Mine

The Stormy Day mine is on the west side of the Selenite Range, 16 miles south of Gerlach, and 2 1/2 miles east of State Highway 34. The mine was discovered in 1941. Over 18,000 tons of ore averaging 0.75% WO_3 have been mined. The mine is developed by adits, drifts, and open cuts.

A body of granodiorite on the west flank of the range intrudes limestone; the contact strikes north-south and dips 50°-70° W. paralleling bedding. Bodies of tactite up to 16 feet thick occur in the marbelized limestone along the contact; the tactite consists mainly of garnet, epidote, pyroxene, and quartz. Scheelite is disseminated through some of the tactite, and to a lesser extent in hornfels which also is present along the contact. The known orebodies occur along only a 750-foot stretch of the contact which extends for several miles. Drilling indicates that the mineralization extends to a depth of at least 425 feet. Pyrite, pyrrhotite, molybdenite, and chalcopyrite also are disseminated through the tactite, but more commonly occur with scheelite and quartz in east-west "cross" shears that cut the intrusive, tactite, and marble; these skarns are up to 10 feet wide.

Vernon Prospect

The Vernon prospect is in Sec. 2, T. 29 N., R. 28 E., in the low, rolling foothills along the east flank of the Seven Troughs Mountains. The prospect is developed by a prospect pit and a 60-foot inclined shaft. Quartz, scheelite, limonite, and molybdenite form small lens in an east-west-trending, 75° west-dipping shear zone in limestone near a "granite" body (Atomic Energy Commission Preliminary Reconnaissance Report N-SL-240). Other scheelite-bearing quartz veins cut the "granite."

Empire Mine

Schrader (1915, p. 340) mentions that molybdenite occurs at the Empire mine in Limerick Canyon in the Rochester mining district. Nothing more is known about this occurrence.

Long Lease Tungsten Mine

The Long Lease (Long) mine is in Sec. 33, T. 26 N., R. 32 E. on the west flank of the West Humboldt Range. Surface and underground workings were made while mining scheelite in tactite in Triassic limestone along a contact with coarse-grained quartz monzonite. On the lower level of the south adit "finely disseminated uraninite and allanite, are associated with pyrite and molybdenite in small zones of silicification" in the limestone and interbedded shale (Davis, 1954).

Nightingale Mining District

The Nightingale mining district is on the east flank of the Nightingale Mountains in Sec. 25, T. 25 N., R. 24 E., in the southwest corner of Pershing County. The tungsten deposits in the district were discovered in 1917. Shipments of tungsten ore have been made off-and-on since then.

Triassic(?) shale and interbedded limestone, striking N. 30° W. and dipping 75° E. to 75° W., have been intruded by a stock of granodiorite. The granodiorite-sedimentary rock contact is nearly vertical, is quite irregular in detail, and commonly cuts the beds of sedimentary rocks at a small angle. Dikes and small bodies of quartz monzonite and quartz diorite intrude both the sedimentary rocks and granodiorite. Tertiary basalt flows and tuffaceous beds overlie the older rocks. The granodiorite stock extends 15 miles to the north, forming the northern part of the Nightingale Mountains, (Smith and Guild, 1942).

A well-developed system of joints occur in the sedimentary rocks, the three most prominent sets of joints being parallel to the bedding, normal to bedding and parallel to lineation, and normal to both bedding and lineation. Post-ore faulting has caused displacements of a few feet, but no faults having large displacements are known in the district.

The sedimentary rocks in contact with the granodiorite stock have been metamorphosed. The shale is changed to siliceous hornfels and mica schist.

The hornfels and schist, while most common near the granodiorite outcrop, also occur at some distance from it. The limestone is altered to dark green-brown tactite, consisting of abundant quartz, plentiful epidote and garnet (pyrope-almandite), much calcite and pyroxene, varying amounts of scheelite, some tremolite, minor pyrite, pyrrhotite, molybdenite, chalcopyrite, and arsenopyrite, and microscopic grains of titanite and apatite. The percentages of the different minerals vary greatly. Outward from the granodiorite contact the tactite grades into lighter-colored, pale green silicated rock consisting mainly of tremolite, diopside, calcite, and quartz. Some of the skarn and sulfide minerals also are present in the granodiorite next to the tactite.

Although much of the tactite is barren, scheelite is locally abundant enough to form small ore bodies. The bodies are irregular, both in shape and distribution within the tactite. Traces of scheelite also are present in the granodiorite.

At the Garfield Force tungsten mine in NW/4 Sec. 31, R. 25 E., T. 25 N., at the south end of the district, specks of scheelite and molybdenite are in a unusual tactite present on the dump at a shallow shaft 1,000 feet northwest of the main adit. The tactite consists mainly of dark green pyroxene and lesser garnet.

Gianella (1941) mentions that powellite is present in the district.

STOREY COUNTY

Comstock Lode

Wulfenite was locally abundant in the oxidized upper few hundred feet of the Comstock Lode. For detailed descriptions of this famous silver-gold fissure-vein deposit the reader is referred to Stoddard (1950, p. 55-70) who lists all the important papers written about its geology and also discusses the evolution of geologic thinking with time.

WASHOE COUNTY

Guanomi Mine

The Guanomi (Foster's Camp) mine is in the SW 1/4 Sec. 24, T. 23 N., R. 22 E., on the southwest side of Pyramid Lake. The mine workings consist of a 900-foot shaft and a 400-foot adit with 400-feet of drifts; all the workings are caved.

Abundant pyrite and lessor molybdenite occur in highly-altered quartz monzonite porphyry. Both minerals are present as disseminations and in quartz veinlets; molybdenite also is present as films ("paint") along fractures. Analyses suggest that the pyrite is cupriferous. Oxidation extends to a depth of less than 10 feet. The outcrop of mineralized rock at the mine covers only a few hundred square yards and is surrounded by Pleistocene beach deposits (see Bonham, 1970, p. 96 and fig. 30).

To the southwest of the mine, quartz monzonite outcrops over an area of more than a square mile. The quartz monzonite intrudes lower Miocene rhyolite welded tuffs and is overlain by Mio-Pliocene basalts and andesites. The interior of the stock is medium-grained, its margins a porphyry. Alteration varies from propylitization of the center of the stock, to intense quartz flooding, sericitization, and pyritization in its margins. The quartz flooding has both silicified the rock and filled fractures with quartz veinlets (Bonham, 1970).

Molybdenite was noted at a few spots in the large outcrop of quartz monzonite, but no drilling has been done to determine the amount of molybdenite present below the oxidized and leached surface zone. More work is needed to determine whether or not a mineable porphyry-type deposit is present in this favorable environment.

Hill-Johnson Prospect

The Hill-Johnson prospect is in Sec. 27, T. 22 N., R. 19 E., at the south end of Freds Mountain. Dark to pale-blue molybdenum-rich stains (ilsemannite?) occur on quartz stringers forming 1- to 2-foot-wide zones in schist. The zone

trends north and dips gently west, and can be traced for several hundred feet (Schilling, 1962, p. 39). The schist is metamorphosed Mesozoic dacitic volcanic rock forming a small roof pendant in a granitic intrusive (Bonham, 1970, p. 97).

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Verdi

The Verdi (Fleisch) occurrence is in Sec. 29, T. 19 N., R. 18 E. at the Fleisch hydroelectric plant in the mouth of the Truckee Canyon. Films of molybdenite coat fractures in altered granodiorite.

Steamboat Springs

At Steam Boat Springs blue, molybdenum-rich stains (ilsemannite?) coat walls of the "upper silica" pit in the center of Sec. 32, T. 18 N., R. 20 E. The pit is in basalt that has been almost completely altered to quartz by hot spring activity.

The Ely (Robinson, Ruth) mining district is mainly in T. 16 N., R. 62 E., in the Eagan Range west of Ely. The district was organized as the Robinson District in 1868. Early mining was for gold and silver. There also has been some production of lead, zinc, and manganese. Mining of the huge porphyry copper deposits began in 1907. The copper deposits are now mined by open-pit methods. In the past, block-caving and more selective underground methods were also used. Kennecott Copper Corp. owns and operates the mines, and a mill and smelter at McGill. Over 60,000,000 tons of ore averaging 1.10 percent copper has been mined from which over 4 billion pounds of copper, over 2 million ounces of gold, 8 million ounces of silver, and over 5 million dollars worth of molybdenum have been recovered, the total value exceeding a billion dollars. This district has been the only important producer of molybdenum in Nevada; molybdenum recovery began in 1941. Only a few, very small shipments have been made from other areas.

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Peavine Mountain

Flakes of molybdenite are present in vuggy quartz on a dump of a caved adit in the SW/4 SE/4 Sec. 36, T. 20 N., R. 18 E. on the south flank of Peavine Mountain. The adit is in altered and iron-stained metamorphic rocks near a granitic intrusive body.

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(For a more detailed description of the history and geology of the porphyry-copper deposits, as well as a list of additional references, see the excellent paper by Bauer and others, 1966.)

The Rocks. In the district, a sequence of generally north-striking, west-dipping Paleozoic limestone, dolomite, shale, and sandstone have been intruded by monzonite. These rocks have been intruded and covered by Eocene-Oligocene rhyolite.

The monzonite bodies are concentrated along an east-west zone some eight miles long. The monzonite is believed to have been intruded during a single epoch, although some bodies have been formed by multiple intrusives. Isotopic age dating indicates that intrusion took place about 120 m.y. ago (Schilling, 1965, and Schilling, in press). The alteration and mineralization are contemporaneous with the intrusion of the monzonite. The bodies are dikes, sills, and "chonoliths," and commonly have very irregular shapes, and diminish in size with depth. Such bodies in the mineralized zone in outcrop vary from 200 to 3,000 feet across, and have roots extending at least 1,600 feet deep. Most of the monzonite is porphyritic to some degree, the principal textural variation being in the groundmass which ranges from microcrystalline to granitic. The intrusives range from quartz monzonite to monzonite in composition, and are composed principally of orthoclase, andesine ($Ab_{50}An_{50}$), and hornblende, varying amounts of quartz, and minor apatite, magnetite, sphene, and zircon.

Structures. The most notable structural feature is the east-west alignment of the monzonite bodies, alteration, and mineralization. The district is on a major east-west lineament traversing eastern Nevada and western Utah, which is believed to be a deep-seated, basement fault that forms a zone of weakness along which igneous activity has taken place. There are numerous pre- and post-ore, high-angle faults, with a predominately north-trend; some of the pre-ore faults locally provide structural controls for the mineralization. Pre-ore thrust faults also are present and locally have acted as barriers to intrusion and mineralization.

Contact Metamorphism. The sedimentary rocks in contact with altered monzonite have been strongly metamorphosed. The limestone at the contact is altered to dense tactite composed of garnet, chlorite, magnetite, specularite, pyrite, and chalcopyrite. The tactite grades outward into garnet-diopside-idocrase-epidote rock, which in turn grades into bleached and recrystallized limestone containing tremolite. The shale is metamorphosed to hornfels. Silicification of the limestone and sandstone has produced dense masses of jasperoid near sericitized monzonite. Contact-metamorphism is weak where the sediments are in contact with unaltered monzonite.

Alteration. Alteration in the monzonite can be divided into three types: (1) quartz-sericite; (2) biotite-argillic; and (3) propylitic. The first two types are associated with ore (and will be discussed further under the porphyry-copper deposits section); the propylitic alteration is not.

Porphyry-Copper Deposits. The porphyry-copper deposits of the district occur along the same east-west zone along which the monzonite intrusive bodies, hydrothermal alteration, and contact metamorphism are concentrated. This zone is readily recognized by bleached limestone, jasperoid, leached monzonite, and limonitic staining.

The ore is mainly in altered, porphyritic monzonite and to a lesser extent in adjacent sedimentary rocks, seldom extending outward more than 300 feet. The rocks in the ore deposits are minutely broken by intersecting fractures having no dominent trend.

Pyrite is pervasive throughout the altered monzonite as disseminated grains, veinlets along fractures, and blebs in quartz veinlets. Chalcopyrite occurs as disseminated grains and only sparingly as blebs in quartz veinlets. The chalcopyrite generally is more abundant where the alteration is of the argillic type. Small amounts of molybdenite and bornite also are present in the ore. The quartz veins are more abundant in areas of sericitic alteration.

In general the ore is higher grade in the monzonite than in the sedimentary rocks. Small amounts of gold and silver occur in the ore.

The molybdenite is present as disseminated flakes, films ("paint") along fractures, and in quartz veinlets. It is more abundant where the alteration is of the sericitic type. The copper ore usually contains 0.01-0.04% MoS_2. The sericitic alteration overlies the argillic alteration, thus molybdenite is more abundant in the upper, and to a certain extent the outer, parts of the ore bodies.

no 9 The molybdenite, like the sericitic alteration, is believed to have been formed during the later stages of mineralization. 9 The ore bodies have been oxidized and the sulfide minerals removed by leaching to a depth of 100 to over 400 feet below the surface. A zone of supergene enrichment generally occurs below the zone of oxidization; here chalcocite replaces pyrite and chalcopyrite as coatings on the sulfide grains. Chalcocite enrichment is more common where the alteration is of the sericite type. Enrichment is usually weak or absent in the sedimentary rocks.

Replacement Deposits. Small replacement deposits are scattered in the limestone along the margins of the porphyry-copper deposits. Their location is controlled by bedding planes. Copper, lead, zinc, silver, gold, and manganese have been produced from these deposits. Fairly-coarse wulfenite was noted in at least one of the lead deposits peripheral to the porphyry-copper deposits (Carl Austin, personal communication).

OTHER OCCURRENCES, WHITE PINE COUNTY

Bald Mountain Mining District

The Bald Mountain mining district is in T. 24 N., R. 57 E., at the south end of the Ruby Range. A large intrusive of quartz monzonite crops out in Water Canyon. The quartz monzonite intrudes Ordovician limestone, quartzite, and shale. Much of the intrusive is unaltered, but locally it is intensely altered to sericite and clay. Masses of jasperoidal quartz locally cement brecciated areas in the intrusive and sedimentary rocks.

Quartz veins containing pyrite and stibnite cut the intrusive and sedimentary rocks near the intrusive. Oxidized replacement bodies consist-

Fig. __. Geologic Map of the Bald Mountain district.

ing of "limonite," pyrolusite, and secondary copper minerals occur in the limestone near the quartz monzonite. Most of the veins and bodies are along fractures or brecciated zones that either strike N. 20° E. and dip vertically or strike N. 60° W. and dip steeply to the south. Scheelite occurs in skarn along the southwest contact of the intrusive.

Gold King Group. Molybdenite is present in pyrite-bearing quartz veins cutting quartz monzonite. The veins are exposed in prospect pits a few hundred feet north of the road up the north fork of Water Canyon, and northwest of the point where the southwest contact of the granite crosses the road (at last N in "Water Canyon" on the U. S. Geol. Survey Cold Creek Ranch 15' topographic quadrangle map.).

Oddie Tunnel. The Oddie Tunnel is on the Blue Bell group of claims in the NW/4 Sec. 22, T. 24 N., R. 57 E., a few hundred feet north of the road along the south fork of Water Canyon. Pyrite and molybdenite are disseminated in a quartz monzonite porphyry dike and the quartz monzonite stock which the dike intrudes. In this area the quartz monzonite stock is sericitized, and contains quartz veinlets. The alteration is most intense along and in the dike.

McMurray Prospect

At the McMurray prospect in NW/4 Sec. 36, T. 24 N., R. 62 E., 2 miles west of the town of Cherry Creek, "an open cut exposes a zone of crushed, iron-stained, silicified quartzite 15 feet wide, which strikes N. 35° E. and dips 70° W. Some narrow quartz stringers cut the zone, and along them the quartzite contains minute specks of pyrite and ... small bluish-gray metallic scales ... [of] molybdenite" (Hill, 1916, p. 41, 167).

Monte Cristo

The Monte Cristo area is in the west-central part of Sec. 21, T. 16 N., R. 57 E. on the west edge of the White Pine Range. A number of companies --- most recently Umount, Homestake, Shell Canadian, and a Phillips-W. R. Grace joint venture --- have drilled porphyry-copper-type mineralization in and adjacent to the altered Monte Cristo quartz monzonite stock. Pyrite and chalcopyrite occur as disseminations and in veins with or without quartz. Molybdenite is present in quartz veins with or without the other sulfide minerals, as films along fractures, and as disseminated flakes. Reportedly much of the mineralization is at depths of over a thousand feet.

Hamilton

Small amounts of wulfenite occur in the lead-zinc-silver deposits west of the main silver deposits of the Hamilton (White Pine) mining district (Schilling, 1962, p. 42) which is in the White Pine Range about 35 miles west of Ely. Humphrey (1960, p. 94-109) describes these deposits, but does not mention the presence of wulfenite.

Ward Mining District

The Ward mining district is on the east slope of the Egan Range, 16 miles south of Ely. Several million dollars worth of silver, lead, and copper have been produced. Deep drillling in 1967 and 1968, in the area of the old mines, located several million tons of new ore at depths of 800 to 1,000 feet.

These deeper deposits presently are being developed jointly by Phillips Petroleum and Silver King mines.

The ore occurs as replacement bodies in the Pennsylvanian Ely Limestone (which was developed by the old mines) and the Mississippian Joana and Devonian Guilmette Limestones (which contain the bodies discovered by the recent drilling) along the contact with several east-trending quartz monzonite porphyry dikes. The ore consists mainly of quartz, pyrite, silver-bearing galena, chalcopyrite, and sphalerite. The chalcopyrite is more abundant in the deeper deposits. Flakes of molybdenite are locally abundant in quartz veins and as disseminations in the dikes, and to a more limited extent the orebodies.

Minerva Mining District

Tungsten ore has been mined from extensive underground and surface workings at the Scheelite Chief, Silver Bell, Oriole, Everit, Lone Buck, Canary Yellow, Zigzag, Hilltop, and Tony mines in Secs. 16, 21, and 28, T. 11 N., R. 68 E., in the Minerva mining district on the west flank of the southern part of the Snake Range.

Scheelite, and traces of tetrahedrite, galena, silver haloid, powellite, and cuprodescloisite occur as shoots in east-striking, north-dipping quartz veins up to 30 feet wide that cut Cambrian limestone. A large granitic intrusive crops out to the north and east, but is not exposed in the vicinity of the tungsten deposits (Lemmon, 1944).

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