CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the Roland Mulchay Mining Collection

ACCESS STATEMENT

These digitized collections are accessible for purposes of education and research. We have indicated what we know about copyright and rights of privacy, publicity, or trademark. Due to the nature of archival collections, we are not always able to identify this information. We are eager to hear from any rights owners, so that we may obtain accurate information. Upon request, we will remove material from public view while we address a rights issue.

CONSTRAINTS STATEMENT

The Arizona Geological Survey does not claim to control all rights for all materials in its collection. These rights include, but are not limited to: copyright, privacy rights, and cultural protection rights. The User hereby assumes all responsibility for obtaining any rights to use the material in excess of "fair use."

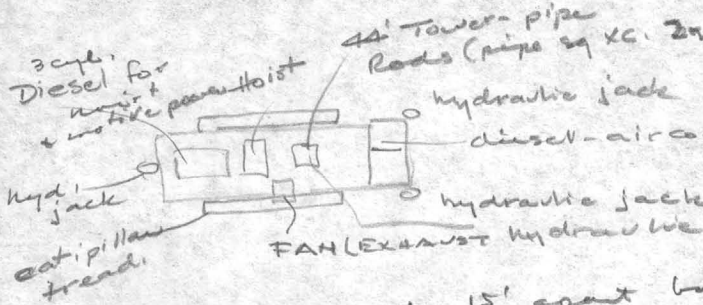
The Survey makes no intellectual property claims to the products created by individual authors in the manuscript collections, except when the author deeded those rights to the Survey or when those authors were employed by the State of Arizona and created intellectual products as a function of their official duties. The Survey does maintain property rights to the physical and digital representations of the works.

QUALITY STATEMENT

The Arizona Geological Survey is not responsible for the accuracy of the records, information, or opinions that may be contained in the files. The Survey collects, catalogs, and archives data on mineral properties regardless of its views of the veracity or accuracy of those data.

TRIP TO SILVER BELL
6/4/52

JOY CHAMPION DRILL
ROTARY, DRY, AIR PRESSURE 80-90#



Holes spaced 15' apart both directions, 7½" bit, 65' deep. Drilling 250 - 300' per shift. in what looks like hard rock. Bits drill up to 3500 ft, cost $135 ea. Move from one location to another in 5-10 min. no collars, but start drilling wet. Recover without dust apparatus, 80% of material from hole. Do not know how deep can drill. Some trouble in very soft ground.

Met Devan x ASTR engineer.
Ward - In charge for Iskell
Keith Smith Drill foreman.

PHOSPHATE MINERALS IN THE CASTLE DOME COPPER DEPOSIT, ARIZONA

BY

N. P. PETERSON

Reprinted from *American Mineralogist*, **32**: 574-582 (1947)

PHOSPHATE MINERALS IN THE CASTLE DOME COPPER DEPOSIT, ARIZONA

BY

N. P. PETERSON

Reprinted from *American Mineralogist*, **32**: 574-582 (1947)

PHOSPHATE MINERALS IN THE CASTLE DOME COPPER DEPOSIT, ARIZONA

N. P. Peterson*

Abstract

Several phosphate minerals occur in the Castle Dome copper deposit near Miami, Arizona, some of which are of special interest because of their uncommon occurrence in deposits of this type. They comprise apatite, turquoise, wavellite, metatorbernite, and libethenite. Apatite is a primary constituent of the quartz monzonite host rock. Turquoise and libethenite are probably supergene minerals, whereas wavellite and metatorbernite may possibly have been introduced by late hydrothermal solutions.

Introduction

The Castle Dome copper deposit is in the Globe-Miami mining district, Gila County, Arizona, five miles west of Miami. The Castle Dome open-pit mine, on the south slope of Porphyry Mountain, is owned and operated by the Castle Dome Copper Company, Inc. It was developed by the owners as a war project, and since June 1943 has produced about 4,000,000 pounds of copper per month.

A detailed study of the Castle Dome deposit and the surrounding area was undertaken by the U. S. Geological Survey in 1943. A complete description will be published by the Survey at a later date.

The writer is indebted to Jewell J. Glass for her work on the properties of the libethenite and for checking the identification of the other minerals described. He wishes also to thank the Castle Dome Copper Company for permission to publish this paper.

The Copper Deposit

The copper deposit is of the disseminated or "porphyry" type. The host rock is a body of quartz monzonite intruded into pre-Cambrian schists and quartzites and possibly into the lower part of the overlying Paleozoic strata. The quartz monzonite is much older than the copper mineralization which is probably genetically related to the Schultze granite south of the deposit. The Schultze granite is of probable late Cretaceous or early Tertiary age.

The most important hypogene sulfides in order of abundance are pyrite, chalcopyrite, and molybdenite. They occur in, or associated with, a set of narrow, closely spaced, generally parallel, quartz veins striking east-northeast and dipping steeply southward. The only other hypogene

* Published by permission of the Director, U. S. Geological Survey.

sulfides, sphalerite and galena, are present in relatively small amounts. They occur accompanied by some quartz, pyrite, and chalcopyrite in veins deposited along faults and major fractures many of which cut across the pyrite, chalcopyrite, and molybdenite veins. The sphalerite-galena veins are banded as if they had been deposited in open fractures, and commonly the vein minerals do not completely fill the fractures. They apparently represent a slightly younger phase of mineralization than the pyrite, chalcopyrite, and molybdenite veins. Small amounts of barite and fluorite, deposited on the walls of open fractures, were also late hypogene minerals.

The mineralizing solutions altered the quartz monzonite bordering the veins to quartz and sericite and caused general argillic alteration of the plagioclase throughout the mineralized area.[1]

Although the ore body is partly the result of higher than average grade copper metallization associated with several gently dipping diabase sills intruded into the quartz monzonite, supergene enrichment played an important role in the formation of the ore. In the upper part of the ore body, chalcopyrite is partly replaced by chalcocite; but the enrichment has not progressed so far that pyrite is replaced except to a very minor extent in a few places. A little covellite is present throughout the the chalcocite zone, but it is generally abundant near the top where it formed by oxidation of chalcocite. Oxidized copper minerals, including malachite, azurite, cuprite, and native copper, occur sparsely throughout the leached and chalcocite zones. Turquoise is also fairly common in these zones.

Phosphate Minerals

In addition to the common sulfides and supergene minerals, a number of phosphates occur in the deposit, some of which are of special interest because of their uncommon occurrence in this type of ore body. They comprise apatite, turquoise, wavellite, metatorbernite, and libethenite. Apatite and turquosie are widely distributed; whereas wavellite, metatorbernite, and libethenite are present only in certain parts of the mine.

Apatite.—Apatite is an accessory constituent of the quartz monzonite host rock in which it occurs associated with biotite in a manner common in rocks of this kind. No apatite introduced by hydrothermal solutions has been recognized. It is mentioned here as a possible source of the phosphate ion in the other minerals.

The phosphate content of the fresh and hydrothermally altered quartz monzonite, as determined by chemical analysis, is shown as follows:

[1] Peterson, N. P., Gilbert, C. M., and Quick, G. L., Hydrothermal alteration in the Castle Dome copper deposit, Arizona: *Econ. Geol.*, **41**, 820–840 (1946).

Sample No	1	2	3	4	5
P_2O_5	.23	.19	.13	.13	.08%

Samples 1 and 2. Unaltered quartz monzonite
Sample 3. Altered quartz monzonite (clay phase)
Sample 4. Altered quartz monzonite (clay-sericite phase)
Sample 5. Altered quartz monzonite (quartz-sericite phase)

Apatite is the only phosphate mineral that was recognized in thin sections of the analyzed rocks. On the basis of these analyses, the fresh rock contains about 0.5 per cent apatite. From 40 to 60 per cent of it is destroyed by hydrothermal alteration. Apatite is generally considered to be a fairly stable mineral but is soluble in acids and is undoubtedly dissolved by supergene solutions to some extent. It could therefore serve as a source of phosphate ion in the formation of supergene minerals.

Wavellite, $3Al_2O_3 \cdot 2P_2O_5 \cdot 13(H_2O, HF)$.—Wavellite is restricted largely to a relatively small elongate area, which trends parallel to the mineralized veins, in the central part of the ore body. It appears to be localized along fractures dipping moderately north to northwestward, which cut the steeply southward dipping veins at approximately right angles. Where open spaces occur along the fractures, wavellite forms encrustations on the walls and on earlier minerals deposited on the walls of the fractures. The crusts consist of coalescing hemispherical masses up to 4 mm. in diameter with radiating internal structure. The surfaces of the hemispheres glisten with light reflected from countless crystal faces. Some of the crusts are clear and colorless, others are gray, yellow or pale-green. In the weathered zone the crusts are usually translucent white or may be stained by iron.

Metatorbernite, $CuO \cdot UO_3 \cdot P_2O_5 \cdot 8H_2O$.—Metatorbernite was first recognized as an artificial mineral by Hallimond.[2] He obtained it by dehydration of torbernite. The first inversion of torbernite in contact with water occurs at 75° C. It is accompanied by a marked change in optical properties and a loss of four molecules of water. A second inversion takes place at 130° C. with further loss of water. The two products were designated by Hallimond as metatorbernite I and II, respectively. He was unable to bring about a reversal of the transformations. Metatorbernite I was later recognized as a natural mineral from Spain and Cornwall by N. L. Bowen.

[2] Hallimond, A. F., The crystallography and dehydration of torbernite: *Mineral. Mag.*, **17**, 326–339 (1916).

The metatorbernite in the Castle Dome deposit was, almost without exception, deposited on wavellite crusts. It occurs as very thin, rectangular, bright-green plates which are usually arranged in tiny rosettes of extraordinary beauty. In some places the crystals form a moss-like mat covering the wavellite crusts. Examined in immersion oils, the crystals are seen to be rectangular or to show rectangular cleavage. Plates lying face up show no birefringence and have an index of refraction of 1.623. The other index is slightly higher. Tilted plates show anomalous purple to violet interference colors and slight pleochroism from yellowish-green to greenish-blue. These properties identify the mineral as metatorbernite I described by Hallimond.[3] Bowen[4] studied the abnormal birefringence of metatorbernite I and found the mineral to be positive for the red end of the spectrum, negative for the blue end, and isotropic in green light at about 515 $\mu\mu$.

The metatorbernite in the Castle Dome deposit is present only in very small amounts.

Libethenite, $4CuO \cdot P_2O_5 \cdot H_2O$.—Libethenite has been found only along fractures related to the Dome fault system which is the most prominent structural feature in the mine and consists of several normal faults trending northeastward through the central part of the ore body. Like wavellite and metatorbernite, it occurs only in open fractures where it forms crusts which are generally composed of tufts of small, emerald-green prisms or a drusy mat of acicular crystals. In some places discrete crystals, some so small they cannot be recognized without the aid of a lens, others up to 1.5 mm. long, lie flat on the rock surfaces.

Jewell Glass of the Geological Survey studied several specimens of the mineral and described its physical and optical properties as follows:

> Crystals are usually short prisms two to five times as long as they are thick, passing into acicular forms grouped in radiating clusters, united in druses. A few crystals show pyramidal habit, resembling octahedrons. Cleavage is good prismatic, luster vitreous, color emerald to yellowish-green, transparent.
>
> Optically the mineral is biaxial negative, 2V large, about 85°. An optic axis emerges normal to a prismatic cleavage or a side pinacoid and looks like the familiar optic axis on epidote grains. The plane of the optic axis is across the elongation. Twinning is observed occasionally. Dispersion is strong, $r > v$. The fragments are pale-green, pleochroism faint, seldom distinguishable. Extinction inclined 0° to 20°, greater than 20° in a few grains. Indices of refraction, average of several readings on each specimen, are: $\alpha = 1.703$, $\beta = 1.746$, $\gamma = 1.789$; $B = 0.086$, all ± 0.002.

[3] Hallimond, A. F., Metatorbernite I, its physical properties and relation to torbernite: *Mineral. Mag.*, **19**, 43–47 (1920).

[4] Bowen, N. L., Abnormal birefringence of torbernite: *Am. Jour. Sci.*, 4th ser., **48**, 195–198 (1919).

The explanation for the anomalous inclined extinction of the libethenite may be revealed by its x-ray diffraction pattern which has not as yet been studied.

Wulfenite, $PbO \cdot MoO_3$.—Wulfenite, although not a phosphate, is discussed here because of its close association with libethenite. It was identified on fragments of rock broken by blasting and has not been seen in place. Instead of the usual tabular crystals, the Castle Dome wulfenite occurs as small, pointed, tetragonal prisms, rarely over 3 mm. long and generally much smaller, which are attached to fragments of rock that apparently formed the walls of open fractures. The surfaces of the rock, as well as some of the crystals, are coated with limonite, jarosite, canbyite, and malachite, all of undoubted supergene origin.

Turquoise, $CuO \cdot 3Al_2O_3 \cdot 2P_2O_5 \cdot 9H_2O$.—Turquoise is fairly widespread throughout the chalcocite zone and in the leached capping. A hard variety of gem quality occurs in small veinlets up to one-quarter inch thick and also in concretion-like masses up to one-half inch thick and several inches across. Its color ranges from sky-blue to bluish-green, the blue variety predominating. It is generally associated with clay minerals and sericite which form selvages on the veins and masses and are commonly included in the turquoise. Seen under the microscope, it it is a microcrystalline aggregate having a mean index of refraction of 1.62.

Much more abundant than the hard blue turquoise is a soft chalky variety which occurs in small masses on the walls of open fractures or filling small fractures. The masses and seams were not formed by alteration or replacement of wall-rock but appear to be accumulations of material transported into the fractures either in solution or in suspension in ground water. Its color ranges from almost white to light-blue when dry and deeper shades of blue when moist. The powdered mineral in immersion oils is almost identical in appearance to the powdered hard variety and has the same index of refraction. When ignited, the powder turns brown, becomes soluble in acid and gives positive reactions for copper and phosphate ions. All gradations between the hard blue turquoise and the white chalky variety can be found.

A few specimens of a light-green, iron-bearing copper aluminum phosphate were found occurring in the same manner as the hard blue turquoise. It is a microcrystalline aggregate whose mean index of refraction is 1.67. Charles Milton of the Geological Survey identified the mineral as a ferrian turquoise. He reports as follows:

> The light-green mineral is identified as turquoise rather than chalcosiderite. These two minerals are considered to be isomorphous with Al_2O_3 and Fe_2O_3, respectively. The x-ray pattern is similar to that of turquoise from Lynch, Va., which presumably

would hardly be distinguishable from chalcosiderite. However, the density (2.75 by pycnometer) and indices of refraction indicate turquoise.

Employees of the mine have been permitted to dig turquoise on days when they were not on duty, and an amazingly large quantity of the mineral has been purchased by dealers in Globe and Miami. Unfortunately no record is available as to the amount of turquoise produced, but undoubtedly the Castle Dome mine is one of the most important sources of gem turquoise at the present time.

Origin of the Phosphates

Although some of the Castle Dome phosphates were probably formed by supergene processes, the lack of valid evidence of supergene origin in the case of wavellite and metatorbernite suggests that they were deposited by hypogene solutions which may represent either the final ebbing stages of the copper mineralization or an entirely different period of mineralization from an independent source. No minerals have been recognized in the deposit from which uranium could have been derived by weathering processes. If it had been leached from undetectible traces present in the country rock, the metatorbernite would be expected to have more general distribution instead of being concentrated in a relatively small portion of the mineralized area. The absence of an obvious source of uranium is probably not conclusive evidence that metatorbernite was deposited by hypogene solutions, however, no evidence has as yet been found that suggests supergene origin.

Metatorbernite is less widely distributed than wavellite which commonly occurs alone; however, metatorbernite is never found unaccompanied by wavellite. It usually occurs on wavellite crusts and is clearly the younger mineral. Metatorbernite has not been recognized in the leached capping. Most of it has been found in the lower part of the secondary sulfide zone; the maximum depth at which it occurs cannot as yet be determined. In a few places, metatorbernite has been dissolved by supergene solutions leaving a very little residue of a yellowish material resembling kaolinite.

The fact that torbernite transforms to metatorbernite I at 75° C. and to metatorbernite II at 130° C. may indicate that metatorbernite I formed at a temperature between 75° and 130° C. which is certainly above the range of supergene solutions; however, it has not been produced artificially except by dehydration of torbernite, hence there is as yet no proof that metatorbernite I cannot be precipitated from solution at temperatures lower than 75° C.

Jewell Glass[5] describes an instance in which the inversion of torbernite

[5] Glass, Jewell J., personal communication.

to metatorbernite I unquestionably took place at room temperature. A specimen of torbernite from Spruce Pine, N. C., stored in a mineral cabinet in the Geological Survey laboratory was reexamined after a lapse of about ten years and was found to have inverted to metatorbernite I. The time required for the inversion to take place at room temperature is not known since no interim examination of the specimen was made; however, it was observed that after a few months, or perhaps years, the emerald-green color of the torbernite had faded to a dull siskin green, and the crystals had lost their transparency.

Very little wavellite has been found in the weathered zone. In a few places in the upper part of the ore body, the wavellite shows evidence of attack by supergene solutions; and some of it is stained by iron oxides; however, much of it occurs in fractures where chalcopyrite is only slightly tarnished by chalcocite and where no other supergene minerals are present. Wavellite commonly crusts pyrite and chalcopyrite, and in one place it was deposited on fresh galena and sphalerite, Many examples of wavellite crusts on barite crystals have been observed.

Wavellite probably forms as a supergene mineral in the weathering of phosphate deposits, but where it occurs in vein deposits it is most likely hypogene, although opinions differ on this point. Lindgren and Ransome[6] describe hypogene wavellite associated with adularia in the Cripple Creek district. Russell[7] describes wavellite in the Castle-an-Dinas wolfram mine in Cornwall so as to suggest to the reader that it is a late hydrothermal mineral. The wavellite in the tin veins of Llallagua, Bolivia, is considered hypogene by Turneaure[8] and Bandy,[9] but Samoyloff[10] and Ahlfeld[11] include it among the supergene minerals. In a later discussion of the same tin deposit, Ahlfeld[12] describes wavellite as one of the latest hypogene minerals.

Libethenite crystals are always present on those surfaces of rock fragments to which wulfenite crystals are attached, but many specimens contain libethenite crystals unaccompanied by wulfenite. Both minerals occur in fractured rocks where oxidation and leaching of sulfides are probably complete. The fractures contain abundant limonite, canbyite, malachite, and jarosite. These minerals are clearly younger than the

[6] Lindgren, W., and Ransome, F. L., Geology and gold deposits of the Cripple Creek district, Colorado: *U. S. Geol. Survey, Prof. Paper* **54,** 176 (1906).

[7] Russell, Arthur, quoted, Russellite, a new British mineral: *Mineral. Mag.*, **25,** 41 (1938).

[8] Turneaure, F. S., The tin deposits of Llallagua, Bolivia: *Econ. Geol.*, **30,** 60 (1935).

[9] Bandy, M. C., Direction of flow of mineralizing solutions: *Econ. Geol.*, **37,** 330 (1942).

[10] Samoyloff, V., The Llallagua-Uncia tin deposit: *Econ. Geol.*, **29,** 495 (1934).

[11] Ahlfeld, F., The tin ores of Uncia-Llallagua, Bolivia: *Econ. Geol.*, **26,** 253 (1931).

[12] Ahlfeld, F., The tin deposits of Llallagua, Bolivia: *Econ. Geol.*, **31,** 220 (1936).

wulfenite, but their relationship to libethenite is not clear. In some places libethenite crystals are engulfed by them, in other places libethenite crystals appear to have formed on limonite crusts. Clumps of libethenite crystals are commonly attached to wulfenite in such a manner as to suggest that libethenite is decidedly the younger mineral. Thin botryoidal crusts of a black manganiferous mineral resembling pyrolusite are often found on the same rock surfaces with libethenite, which in some examples forms crusts on the manganese mineral. No other occurrence of manganese oxides has been noted in the Castle Dome deposit, hence it is considered to be related to this phase of mineralization. On some rock fragments, barite crystals are attached to the same surfaces as are wulfenite and libethenite, and both minerals appear to have formed on barite crystals.

Although wulfenite and some of the libethenite is clearly older than such definitely supergene minerals as limonite, malachite, canbyite, and jarosite, little evidence can be cited to support a postulation that they were deposited by late hypogene solutions. The usual difficulty in accounting for a source of molybdenum to produce wulfenite by supergene processes is solved in this deposit by the presence of molybdenite, which, although very resistant to oxidation, has been altered to the oxide to some extent; and therefore some molybdenum may have been transported by supergene solutions. Likewise a source of lead is available in galena which is more abundant along the Dome fault system than elsewhere in the deposit. However, Dittler's [13] experiments on the synthetic production of wulfenite indicate that an alkalic environment is necessary, and therefore wulfenite is not likely to be formed by supergene solutions. He concludes that it is formed by rising alkaline solutions which reacted with lead carbonate.

Sources of the constituents of libethenite are also readily available in this deposit. The copper could have been derived from hypogene chalcopyrite, and phosphate ion from apatite or wavellite. Lindgren[14] found small crystals of libethenite in cavities and seams in quartzite in the oxidized zone of the Coronado vein in the Clifton-Morenci district. He considered it to be a supergene mineral.

On the basis of field evidence, wulfenite and libethenite are clearly late minerals and may well be of supergene origin; however, wulfenite is earlier than libethenite, and the two minerals are not necessarily genetically related. Their association could easily be coincidental.

[13] Dittler, E., Further experiments on the synthetic production of wulfenite: *Zeits. Kryst. Min.*, **54**, 332–342 (1914).

[14] Lindgren, W., Copper deposits of the Clifton-Morenci district, Arizona: *U. S. Geol. Survey, Prof. Paper* **43**, 118 (1905).

Turquoise is generally conceded to be a supergene mineral, formed by the action of ground-water solutions, carrying copper and phosphate ions, on kaolin and possibly sericite. Various writers describe all stages in the alteration from copper-stained kaolin to hard blue turquoise; but it is not usually clear from the published descriptions whether the mineral is kaolinite or some other clay. Kaolinite is not a common mineral in the Castle Dome deposit, and its association with turquoise has not been noted; however, turquoise is commonly associated with beidellite, halloysite, and sericite. No evidence has yet been found suggesting that it forms from clay. The hard blue turquoise grades into the soft, white clay-like variety; but the index of refraction of all of it is near 1.62, which is much higher than that of any of the clays present. None of the material could be construed as being transitional between turquoise and the associated clays.

Although turquoise is most abundant in the upper part of the secondary sulfide zone, it is commonly found in deep fractures where chalcopyrite is only slightly replaced by chalcocite or not at all. If turquoise was formed by supergene solutions, the phosphate ion would have to be derived from either wavellite or apatite which are the only earlier phosphate minerals. Wavellite is apparently dissolved by supergene solutions, but much turquoise occurs in parts of the mine where no wavellite has been recognized. In the Castle-an-Dinas mine in Cornwall,[15] wavellite spheres are commonly covered by minute botryoidal aggregates of bright-green turquoise, but no such association has been seen in the Castle Dome deposit. Most writers look to apatite as the probable source of phosphate ion even though admitting in some cases that the country rock contains very little apatite.

[15] Hey, M. H., and Bannister, F. A., Russellite, a new British mineral: *Mineral. Mag.*, **25**, 41 (1938).

LANCASTER PRESS, INC., LANCASTER, PA.

HYDROTHERMAL ALTERATION IN THE CASTLE DOME COPPER DEPOSIT, ARIZONA.

N. P. PETERSON, C. M. GILBERT, AND G. L. QUICK.

Reprinted from ECONOMIC GEOLOGY, Vol. XLI, No. 8, December, 1946

Reprinted from ECONOMIC GEOLOGY, Vol. XLI, No. 8, December, 1946
Printed in U. S. A.

HYDROTHERMAL ALTERATION IN THE CASTLE DOME COPPER DEPOSIT, ARIZONA.[1]

N. P. PETERSON, C. M. GILBERT, AND G. L. QUICK.

ABSTRACT.

Hydrothermal alteration of the quartz monzonite host rock in the Castle Dome copper deposit consists of three phases. Very weak propylitic alteration of biotite and plagioclase occurs in the marginal part of the mineralized area. Where mineralization is stronger most of the plagioclase and some of the orthoclase and biotite are replaced by a montmorillonite-type clay, resembling beidellite, and hydrous mica. The third phase is localized along quartz-pyrite veins where the wall rock, commonly as much as an inch from the vein, is replaced by quartz and sericite. In contrast to the localization of quartz-sericite alteration along the veins, clay alteration is general and can be seen between the veins wherever the rock is not completely sericitized. Thus these two types of alteration cannot be separated areally. The most intense clay alteration together with moderate quartz-sericite alteration occurs in the ore body, whereas the strongest quartz-sericite alteration, where pyrite veins are largest and most numerous, is in a zone along the north side of the ore body.

INTRODUCTION.

THE Castle Dome copper deposit is in the Miami mining district, Gila County, Arizona, 7 miles west of Miami. The Castle Dome open cut mine on the south flank of Porphyry Mountain is owned and operated by the Castle Dome Copper Company, Inc., a subsidiary of the Miami Copper Company. It was developed by the owners as a war project, and since June, 1943 has produced about 4,000,000 pounds of copper per month.

The general geology of the Globe quadrangle (Fig. 1), which includes the Castle Dome area, was studied by F. L. Ransome[2] in 1901 and 1902, and an account of the Miami-Inspiration copper deposit by Ransome[3] was published in 1919. The present study in much greater detail was carried on by the Geological Survey during the period from July, 1943 to September, 1944 and was confined to the area surrounding the Castle Dome mine. Fig. 2 is a generalized geologic map of the area compiled from a detailed map on a scale of 1 : 2,400.

We wish to acknowledge the cordial co-operation of the staff of the Castle Dome Copper Company, especially R. W. Hughes, Manager, B. R. Coil, General Superintendent, and J. C. Van de Water, Mine Superintendent. We received suggestions from many of our colleagues in the Geological Survey. We

[1] Published by permission of the Director, Geological Survey. Presented before the Society of Economic Geologists, Pittsburgh Meeting, Dec., 1945.
[2] U. S. Geol. Surv. Prof. Paper 12, 1903.
[3] U. S. Geol. Surv. Prof. Paper 115.

are particularly indebted to C. S. Ross, B. S. Butler and T. S. Lovering for valuable assistance and advice. Thanks are also due Adolf Pabst for criticism of this paper.

GENERAL GEOLOGY.

The copper deposit occurs in a body of quartz monzonite intruded into Pinal schist and Apache group of pre-Cambrian age and possibly into the

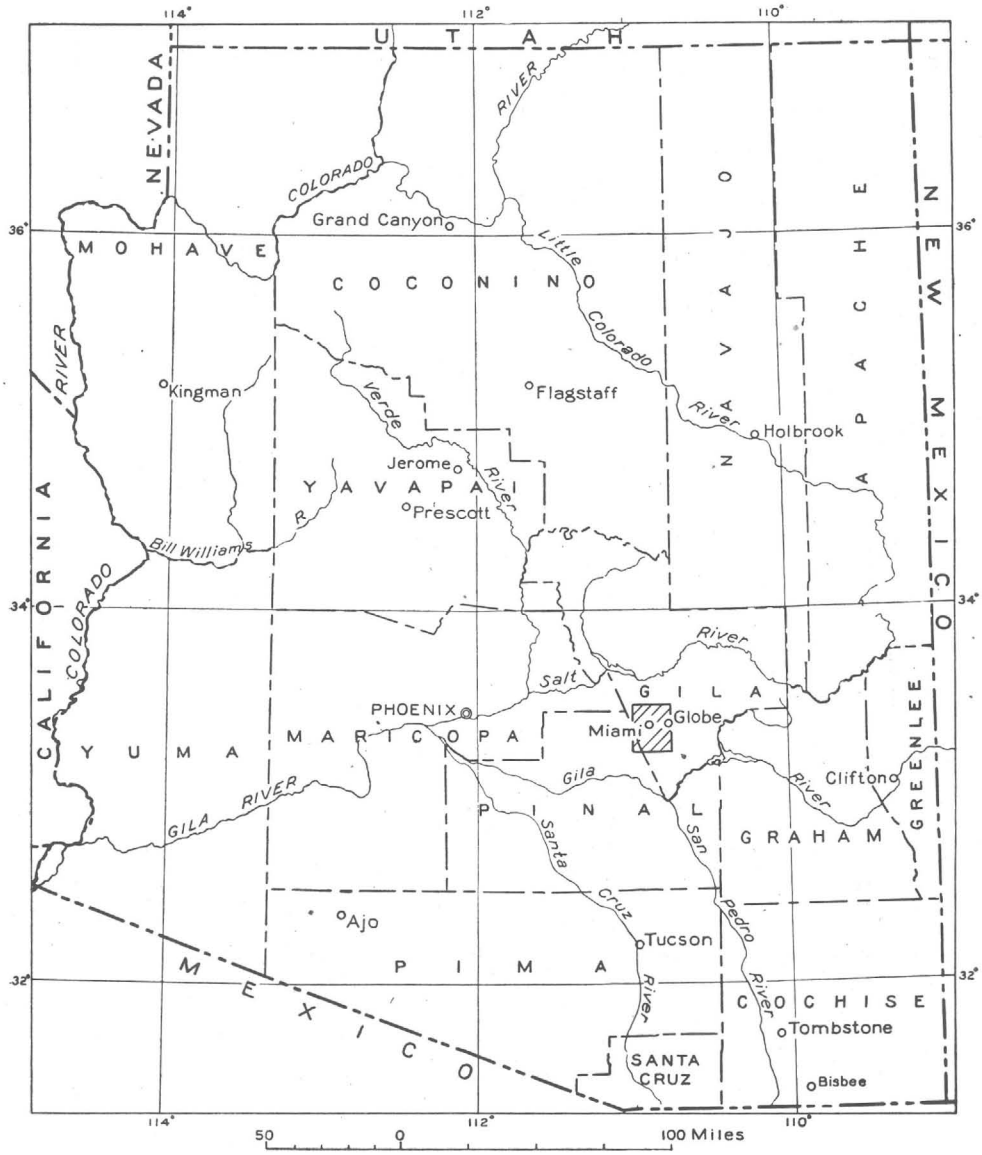


FIG. 1. Index map of Arizona showing location of the Globe quadrangle.

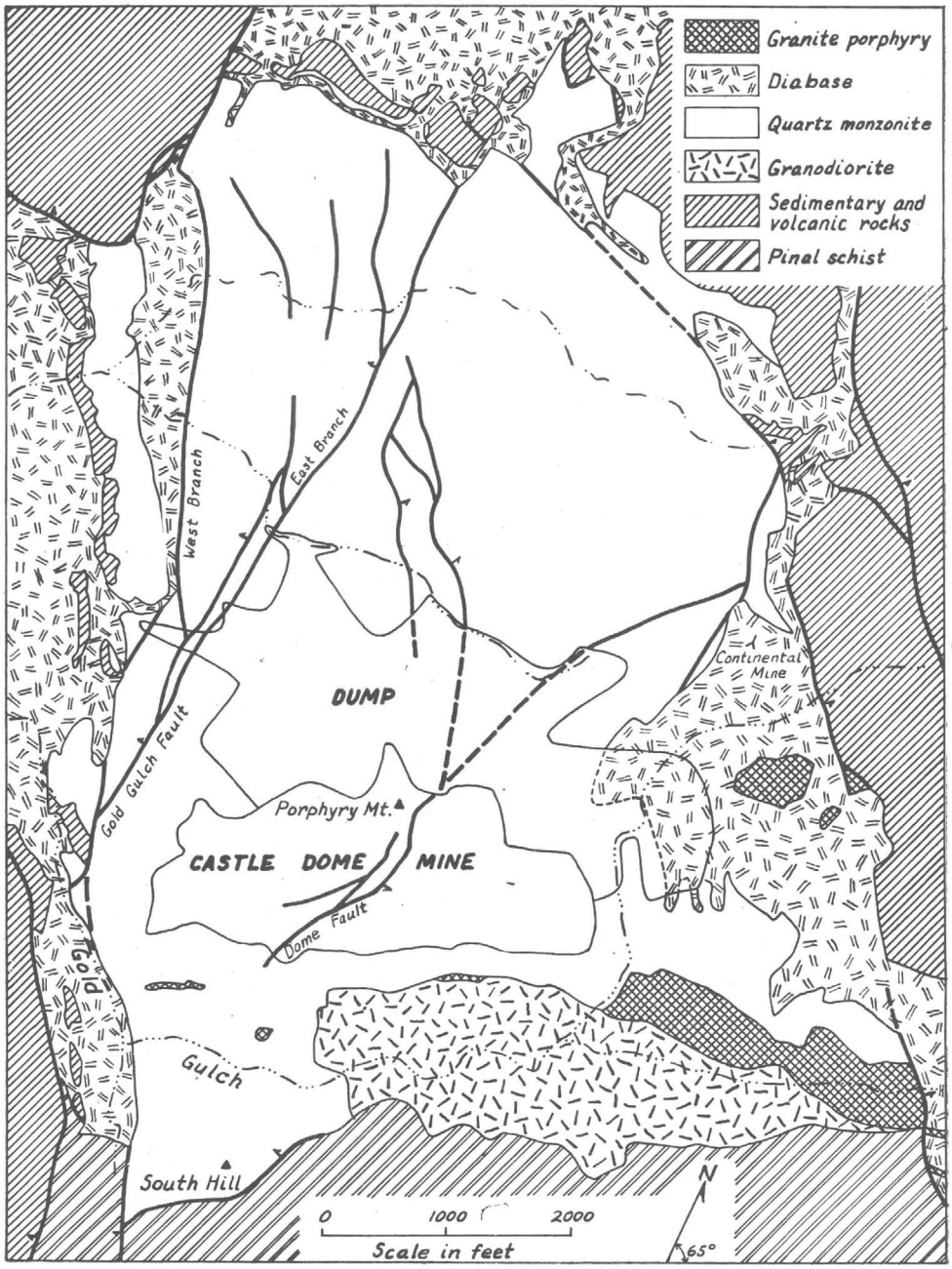


FIG. 2. Generalized geologic map of the Castle Dome area.

lower part of Paleozoic limestones (Fig. 1). The quartz monzonite was preceded by a small intrusion of granodiorite which crops out along its south side. Following the quartz monzonite intrusion the area was cut by normal faults, and large volumes of diabase were injected as thick sills and dikes. Small bodies of granite porphyry were later intruded mainly along the south edge of the quartz monzonite. In late Tertiary time the region was covered by a thick flow of dacite lavas. Following the dacite eruption, erosion again exposed the older rocks in some areas, in others Gila conglomerate accumulated as valley fill. Probably all of the Castle Dome area was low and covered by Gila at that time.

The dominant structure of the Castle Dome area is a horst trending in a north-northwest direction, and within it the quartz monzonite is confined. The horst is bounded on the east and west sides by steeply-dipping normal fault systems along which the quartz monzonite was brought in fault contact with Paleozoic and Apache rocks. Diabase was intruded along the marginal faults and now generally separates the quartz monzonite from the relatively depressed blocks of sedimentary rocks on the east and west sides. A second and smaller horst, trending in a northerly direction, is bounded on the west by the East Branch of the Gold Gulch fault, which dips west, and on the east by the east-dipping Dome fault system and a group of east-dipping faults north of the mine. Normal faulting occurred at intervals until early Quaternary time, and all formations of the region except recent alluvium have been displaced.

HYPOGENE METALLIZATION.

The hypogene metallization is almost entirely confined to the granite porphyry and the southern half of the quartz monzonite body. It occurs mainly in narrow, closely spaced, generally parallel veins, which strike N. 75° E. and dip steeply southward, but some sulphides are disseminated in the wall rock between the veins. The principal hypogene vein minerals in order of abundance are quartz, pyrite, chalcopyrite and molybdenite. A few younger veins containing sphalerite and galena cut across the pyrite, chalcopyrite and molybdenite veins.

The distribution of the primary sulphide minerals shows distinct zoning. The zones trend parallel to the strike of the veins and are probably also parallel in dip. One zone, in which the mineralization is mainly pyrite with very little chalcopyrite (0.01 to 0.15 per cent Cu), extends across the quartz monzonite through the summit of Porphyry Mountain (Fig. 3).
Northward the mineralization in this zone decreases gradually to where it is no longer recognizable in the outcrops. South of the pyrite zone and parallel to it is a zone containing less pyrite and more chalcopyrite. The hypogene mineralization in this zone is estimated to average about 0.3 per cent copper and is the protore of the ore body. Molybdenite is most abundant in a zone which overlaps the southern edge of the pyrite zone and the northern edge of the chalcopyrite zone.

A second smaller zone of high pyrite metallization occurs along the north side of the fault which forms the contact between the schist and quartz mon-

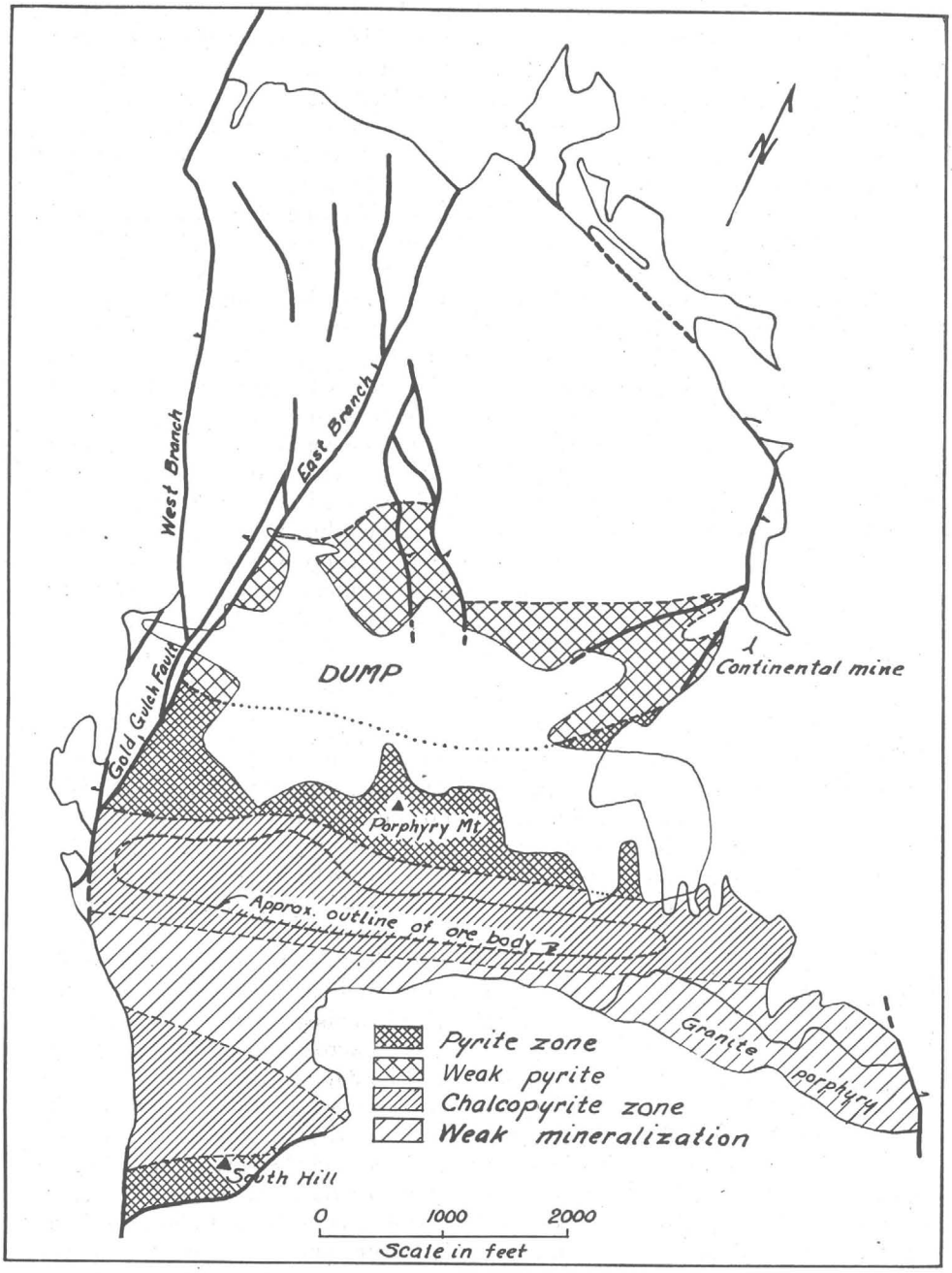


FIG. 3. Outline of the quartz monzonite showing generalized pattern of hypogene mineralization.

zonite on the south side of South Hill at the southwest corner of the quartz monzonite body (Figs. 2 and 3). This high pyrite zone is flanked on the north by a chalcopyrite zone in which a small ore body has been produced by supergene enrichment.

Several thin, fine-grained diabase sills crop out along the south side of the main ore body and dip gently northward through the mine. The copper content of the rock is invariably higher than average in and near these sills.

The quartz monzonite is much older than the mineralization and served merely as host rock. Hypogene mineralization was more nearly contemporaneous with the granite porphyry intrusions than with any other igneous rock of the region and is therefore probably genetically related to the porphyry. The association of copper mineralization with granite porphyry intrusions is characteristic of the Miami district. In each of the major mineralized areas of the district granite porphyry is present and is mineralized, but the main ore bodies occur in the adjacent rocks which are either schist or quartz monzonite.

The Castle Dome ore body is the result partly of supergene enrichment and partly of the richer hypogene mineralization associated with the diabase sills. A leached capping, which averages about 80 feet thick and generally contains less than 0.1 per cent copper, overlies the ore body. Except for the copper enrichment of the hypogene chalcopyrite and pyrite, the supergene alteration has not greatly affected the products of hydrothermal alteration.

THE QUARTZ MONZONITE HOST ROCK.

The quartz monzonite has a generally uniform mineral composition, essentially quartz, orthoclase and oligoclase. Subhedral books of dark brown biotite, commonly including oriented needles of rutile, are characteristic of the rock but are not abundant. Minor accessory minerals are zircon, apatite, sphene and ilmenite. Zircon is decidedly rare and occurs in very small crystals, whereas the others are more common and generally are clustered near the biotite crystals. The orthoclase is evenly distributed throughout the quartz monzonite as large pink or reddish brown microperthitic phenocrysts having an almost equant form ranging from 1 to 3 inches across. Most of them poikilitically enclose small oligoclase crystals in a zonal arrangement, and some have rims of oligoclase (rapakivi structure). Without exception the phenocrysts rimmed by oligoclase have round or oval cross-sections, whereas the unrimmed phenocrysts are euhedral.

Although the general composition of the rock appears to be uniform throughout the map area, there are some local variations in the relative amounts of the essential minerals so that here and there the rock might be called granite on the one hand or granodiorite on the other.

Two widespread textural varieties have been distinguished and separately mapped, but although they differ in texture the mineral composition of the two is approximately the same. One variety is porphyritic quartz monzonite containing large phenocrysts of pink or reddish orthoclase in a coarse-grained groundmass, the other is quartz monzonite porphyry containing phenocrysts of orthoclase, quartz, oligoclase and biotite in a fine-grained groundmass.

The contact between them is sharp in many places; elsewhere it seems gradational but is generally definite outside the area of most intense hydrothermal alteration. Quartz monzonite porphyry occurs in the central part of the Porphyry Mountain area and is nearly surrounded by the porphyritic quartz monzonite. The two phases probably represent intrusive pulses of the same magma, the porphyry being slightly younger.

No appreciable difference in either mineralization or hydrothermal alteration is recognizable in adjacent bodies of the two phases of quartz monzonite.

HYDROTHERMAL ALTERATION OF THE HOST ROCK.

General Description.—The hydrothermal alteration that accompanied the copper mineralization in the Castle Dome area consists of three phases (Fig. 4). A very mild phase of the propylitic type, in which biotite and plagioclase are partly altered to sericite, epidote, clinozoisite, chlorite and calcite, occurs in an outer zone where mineralization is very weak, and extends beyond the area where mineralization and alteration can be recognized in the field. This zone surrounds an area of stronger alteration where most of the plagioclase and a little of the orthoclase and biotite are replaced by a montmorillonite-type clay. The clay or argillic [4] phase of alteration is most intense in the mine area and diminishes gradually toward the north and south where more fresh plagioclase together with the alteration products of the propylitic phase is evident. The third phase of alteration, which will be referred to as the quartz-sericite phase, is related to numerous small quartz-pyrite veins along which the wall rock is replaced by quartz, sericite and a little pyrite and adularia. Each quartz-pyrite vein is bordered by a white zone from a fraction of an inch to several inches wide where the wall rock has been mostly replaced by quartz and sericite. Although veins bordered by quartz-sericite alteration occur throughout the mineralized area, they are most numerous, largest, and have the widest alteration borders near the summit of Porphyry Mountain. This area of most intense quartz-sericite alteration is entirely within the clay zone and might be said to represent a third and inner zone of alteration. However, clay alteration is strong in the wall rock between the veins and the two phases cannot be separated areally. Thus although quartz-sericite alteration should be regarded as a separate phase it is superimposed on the clay phase as well as the propylitic phase and actually does not constitute a separate zone.

Propylitic Alteration.—In the marginal part of the mineralized area, entirely outside the mine, the host rock shows the effects of very weak alteration which produced minerals characteristic of propylitization. So feeble is the alteration that the rock, in hand specimens, looks fresh except for a slight greenish coloration of the biotite due to replacement by chlorite. The minerals produced during this phase of alteration are seen under the microscope to include pyrite, chlorite, epidote, clinozoisite, sericite, calcite, and leucoxene, but

[4] Term used by Lovering to describe the effects of hydrothremal alteration that has resulted in the prominent development of clay minerals. Lovering, T. S.: The origin of the tungsten ores of Boulder County, Colorado. ECON. GEOL. 36: 236, 1941.

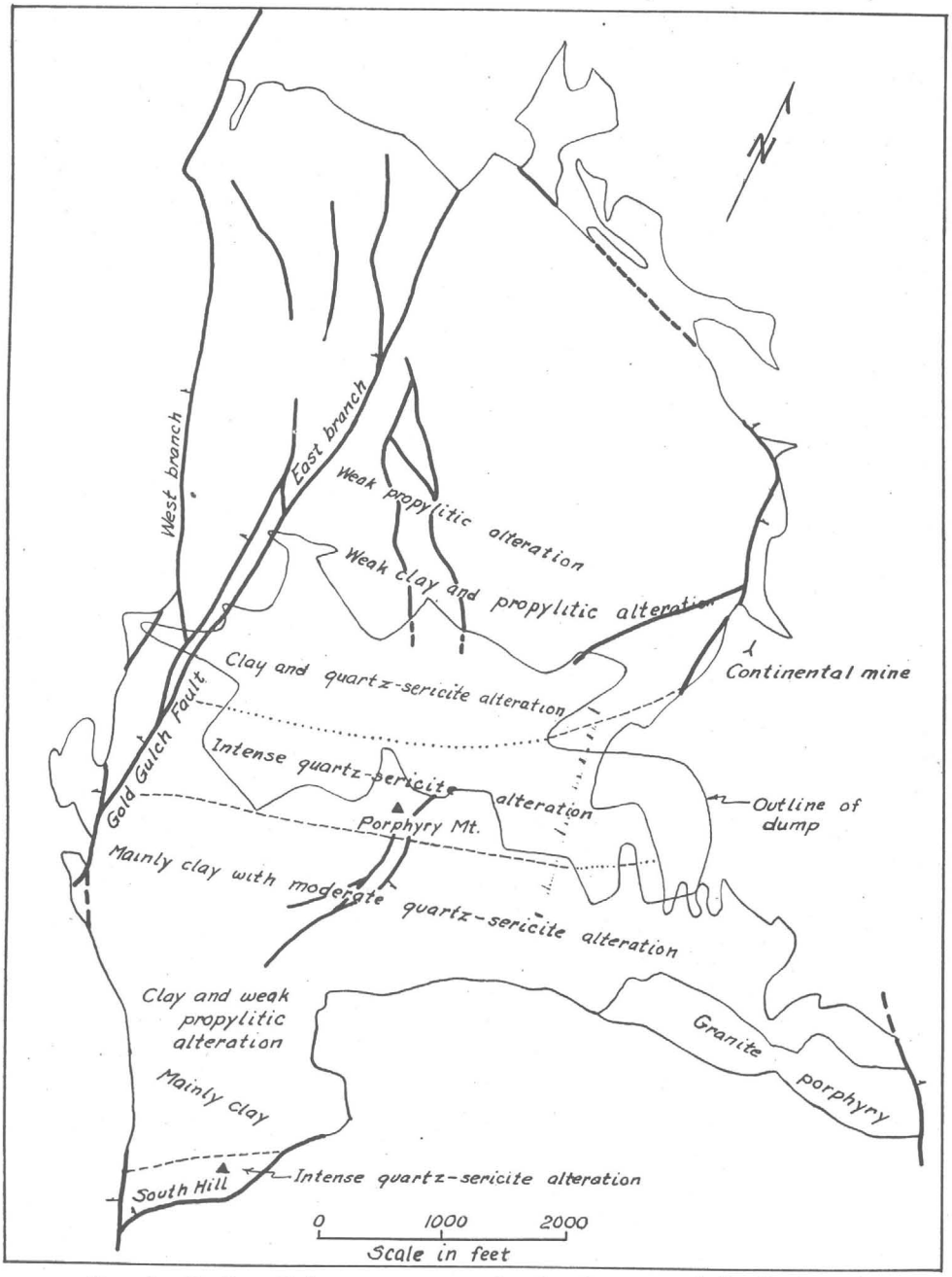


FIG. 4. Outline of the quartz monzonite showing general distribution of alteration phases.

their occurrence and small amount suggest that they are the result essentially of recrystallization without appreciable change in the bulk chemical composition of the rock.

Of the original rock minerals, quartz, orthoclase, and apatite were not affected by propylitic alteration. Biotite and plagioclase are invariably altered but nowhere completely replaced. Sphene is partly or completely converted to leucoxene, but ilmenite shows only thin leucoxene rims. Sphene apparently is most susceptible to attack and is commonly altered to leucoxene where the other minerals are largely fresh.

Commonly most of the biotite remains unaltered but some of it is partly replaced along cleavages by green chlorite having anomalous blue birefringence, and a few completely replaced crystals are chlorite pseudomorphs. Epidote and a little clinozoisite, in addition to chlorite, partly replace some biotite, and where they are absent calcite commonly occurs. Some of the oriented rutile needles which form inclusions in most of the unaltered biotite, and possibly some small inclusions of ilmenite and sphene, are recrystallized to scattered rutile granules or leucoxene.

Plagioclase invariably contains plates and veinlets of sericite oriented approximately parallel to the twinning plane (010) and at right angles to it. Sericite is scattered uniformly through some plagioclase crystals, but in others it occurs in patches here and there. It is commonly accompanied by stringers and scattered tiny grains of clinozoisite or epidote. In contrast to the altered biotite in which more epidote than clinozoisite occurs, altered plagioclase contains much more clinozoisite than epidote. A few crystals are replaced almost completely by clinozoisite. A little chlorite in veinlets and as rosettes is present in some of the plagioclase, and where epidote and clinozoisite are absent calcite occurs.

Clay Alteration.—Throughout the mine area, except in the sericitized borders of quartz-pyrite veins, the quartz monzonite looks almost fresh. The main alteration noticeable in hand specimens is in the plagioclase which has a chalky appearance and rarely shows any twinning striations. Some of the biotite also is altered to a soft, buff-colored micaceous mineral either in the form of pseudomorphs or aggregates. However, the rock, generally, has retained its original color and texture. Under the microscope the plagioclase is seen to be largely replaced by clay minerals. Because of this it slakes quickly in water and the broken rock in the mine crumbles rapidly during rainy weather. In some places the plagioclase is stained a light brown color probably by included limonite in the clay, and when it is moist, it commonly has a pale greenish color due to adsorbed copper sulphate.

The minerals of the quartz monzonite have been selectively attacked in the course of the clay alteration. Quartz and orthoclase were stable except in a few places where the alteration is most intense, and a few tiny veinlets and small patches of clay replace both minerals. Biotite was relatively stable but was bleached and partly replaced by clay where the alteration was severe. Plagioclase was the least stable of the original minerals, and in many places where the biotite remains nearly fresh the plagioclase has been completely re-

placed by clay. Sphene and ilmenite were converted to leucoxene or fine grained rutile, and most of the apatite has been destroyed.

Variations in the intensity of the clay alteration in the mine are rarely evident except under the microscope. The study of thin sections clearly shows that the amount of clay varies from place to place but no systematic arrangement of these variations has been recognized. The alteration was probably more severe along some of the larger fractures, but every part of the rock within the clay zone was affected to some degree. This is in marked contrast to the localization of quartz-sericite alteration along veins which cut both the argillized and propylitized zones. The only systematic variation observed in the general clay alteration is a decrease in the amount of clay minerals both north and south of the mine area.

The zones of clay and propylitic alteration overlap as an ill defined zone where both are represented. In this zone of overlap, which is best developed north of Porphyry Mountain, clay occurs in plagioclase together with scattered sericite and a little clinozoisite, epidote, and chlorite; biotite is partly replaced by chlorite and epidote but mostly is unaltered. Much of the original sphene is converted to leucoxene, but apatite is fresh. The propylitic alteration of the marginal zone is undoubtedly a feebler phase of alteration than the clay phase. The overlap might suggest that clay alteration encroached on propylitic alteration. However, in the mine, which is entirely within the clay zone, nothing indicates that the rocks were propylitized before the clay alteration occurred. Fresh original biotite is common, and even slight replacement of it, or of plagioclase, by chlorite is decidedly rare. No epidote or carbonates have been found in the mine. However, scattered fine sericite which is not apparently related to veins occurs in the plagioclase throughout the mine and probably developed ahead of the clay alteration.

The dominant clay mineral is a colorless or slightly yellowish montmorillonite-type clay which has been tested by C. S. Ross [5] of the Geological Survey by means of differential heating methods. He reports:

> "This shows that the material gives a typical montmorillonite curve, and also shows very clearly that the exchangeable base is calcium."

J. M. Axelrod of the Geological Survey made an x-ray analysis of the argillized plagioclase and found that it contains a member of the montmorillonite group, muscovite and a very little plagioclase. The clay mineral has a refractive index for beta of 1.545 and a birefringence of 0.02 +. It is tentatively called beidellite because it corresponds approximately to beidellite described by Lovering [6] in the altered rocks bordering tungsten veins in Boulder County, Colorado. Examination of the argillized plagioclase by immersion methods reveals minor amounts of another clay mineral whose refractive index is near 1.52 and a very small amount of an isotropic mineral of low refractive index which is probably allophane.

Beidellite occurs alone in veinlets, as very fine aggregates, and as scattered larger flakes. It is generally associated with some sericite and a micaceous

[5] Ross, C. S., personal communication.

[6] Lovering, T. S., The origin of the tungsten ores of Boulder County, Colorado. ECON. GEOL. 36: 229–279, 1941.

mineral having indices of refraction between those of beidellite and sericite, which is undoubtedly hydrous mica. Hydrous mica cannot be distinguished from muscovite by means of x-ray patterns.

Under the microscope the replacement of plagioclase by clay can be seen in various stages of completion. Where incomplete, irregular patches and replacement veinlets of the clay mixture occur in the plagioclase apparently uncontrolled by the crystal structure of the plagioclase. Though the clay mixture may replace any part of the original plagioclase grains, it commonly has replaced the central part leaving a less altered rim where replacement is less complete. In some parts of the mine the original plagioclase has been entirely replaced, and where this has happened orthoclase and biotite have also commonly been partly replaced by clay minerals, indicating a local area of more intense clay alteration.

Nearly everywhere small blades and veinlets of sericite are scattered through both plagioclase and the clay that replaced it. Whether the sericite occurs in the plagioclase or in the clay it is generally oriented in two directions, one parallel to the twinning striations of the plagioclase and the other approximately at right angles to them. Where replacement of the plagioclase by clay is not complete, there is less sericite in the clay than in the remaining plagioclase; and where the replacement is complete sericite is less abundant or even absent. This observation by itself might indicate either that sericite replaced plagioclase more readily than clay, or that clay has replaced sericite developed in the plagioclase ahead of the clay alteration. Because the sericite in the clay has the same orientation that it has in the plagioclase, it seems likely that this sericite formed early and was later partly replaced by clay. Indeed some sericite flakes scattered through the clay are ragged as though slightly replaced; and in some partly altered plagioclase, tiny sericite veinlets along twinning planes (010) continue from the fresh plagioclase into the clay as ragged trains of sericite flakes. A few plagioclase crystals completely replaced by clay contain some large flakes of beidellite scattered through a very fine-grained clay matrix. Many of the beidellite flakes are oriented and some occur in parallel stringers suggesting perhaps that the early sericite in the plagioclase has been pseudomorphed by beidellite.

A very few grains of blue tourmaline occur here and there in the argillized plagioclase.

Much of the biotite in the clay zone is unaltered but in areas of relatively intense clay alteration it is commonly bleached. The area of most general bleaching is in the west central part of the mine suggesting stronger clay alteration there than elsewhere. The original brown biotite is converted to a colorless or buff-colored mineral of micaceous habit that generally pseudomorphs the original biotite. The mineral looks much like sericite in hand specimens but is softer. Where the bleaching is incomplete, fresh biotite grades into the bleached product. The mineral has a variable but generally low birefringence and refractive index that varies but has a minimum value of about 1.550; it is biaxial, having a negative sign and an optic axial angle (2V) that is small but variable. The bleaching process is probably a simple leaching of the bases from biotite without noticeable recrystallization and the ultimate

product appears similar to kaolinite. In some places beidellite replaces both fresh and bleached biotite.

In the clay zone, sphene and ilmenite, which are generally associated with biotite in the fresh rock, are recrystallized to leucoxene or fine grained rutile. The outlines of euhedral sphene crystals are commonly preserved by the rutile aggregates. Where biotite is altered the rutile inclusions originally present in it have also been recrystallized to tiny granules.

Apatite also is generally associated with biotite in the fresh rock and is most abundant as inclusions in the biotite. In the clay zone it is rare or absent. Where fresh biotite remains, cavities having the shape of apatite crystals indicate that apatite was originally present; but only a few grains, which are commonly corroded, remain.

All of the plagioclase in the diabase sills in the mine has been replaced by clay. Although the composition of the original plagioclase in these sills is unknown, it was undoubtedly more calcic than the oligoclase in the quartz monzonite. Some of the green biotite in the sills has been bleached and partly replaced by clay, and a few veinlets of clay cut the sparse quartz grains that are generally present in the diabase. Leucoxene, developed by the alteration of ilmenite, is abundant. In addition to the clay replacing the minerals of the diabase, thin veinlets of beidellite occur along many of the fractures in the brecciated sills. The rock usually breaks along these seams, and the fragments are coated with the white clay.

Quartz-Sericite Alteration.—Each quartz-pyrite vein is bordered by a narrow zone of alteration where the rock is replaced by sericite and quartz with a little pyrite and adularia. Along tiny veinlets the alteration extends only a fraction of an inch into the wall rock; but along larger veins and particularly where pyrite is abundant, the sericitized borders are commonly several inches wide. Within these glistening white border zones the original texture of the rock is either obscure or completely destroyed. The general effect is that of a layer of intense alteration separating each vein from rock of more normal appearance; and because the veins are numerous and generally parallel, the alteration borders along them appear as thin white stripes cutting through rock in which the original color and texture are generally preserved. In a few small areas in the mine, particularly north of the ore body where veins are large and most numerous, the alteration borders along the veins coalesce, and the rock is completely replaced by sericite and quartz. The outer margin of the quartz-sericite alteration along veins is not abrupt, though in hand specimens it commonly appears to be. Sericitization persists farthest from the veins in those original minerals that are most susceptible to alteration. Close to the veins, plagioclase and clay are completely replaced by sericite; orthoclase and biotite are replaced by both quartz and sericite; and original quartz is partly replaced by sericite. Rutile and zircon are the only minerals not attacked. Beyond a certain limit original quartz and orthoclase are essentially unaltered, but sericitization of plagioclase and clay and of some biotite persists farther from the vein. Thus plagioclase and clay are most susceptible to alteration, and biotite is more stable but breaks down more readily than quartz or orthoclase. Apatite is rare having been largely leached during the clay

phase of alteration. What commonly appears in hand specimens to be a sharp outer limit of the sericitized border along a vein is simply that limit where orthoclase ceases to be sericitized and a change in the general color of the rock occurs because of the contrast between the fresh reddish orthoclase and the glistening white sericite.

Relatively little quartz-sericite alteration occurs along veins without pyrite or veins containing only a little pyrite associated with other sulphides. In a single small area, quartz-pyrite veins bordered by pronounced zones of alteration may be present along with other veins containing barren quartz, or chalcopyrite or molybdenite with quartz, that cut sharply through what appears to be unsericitized rock. Indeed some chalcopyrite veinlets cut through large orthoclase phenocrysts without producing noticeable alteration. Microscopic study, however, generally reveals a little sericitization of the wall rock along chalcopyrite and molybdenite-bearing veins; and feldspars cut by these veins may be slightly replaced by quartz. However, none of the original minerals is completely replaced and in hand specimens the alteration is not evident. Pyrite-free veins do occur close to or actually intersect quartz-pyrite veins and therefore occur in the alteration zones along pyrite veins, but all positive evidence indicates that intense quartz-sericite alteration is related to the quartz-pyrite veins and that only minor silicification and sericitization accompanied the chalcopyrite and molybdenite phases of the mineralization.

Veins containing adularia can rarely be recognized in the field, but thin sections show that a small amount of adularia is common in veins containing chalcopyrite or molybdenite. Adularia also occurs in the walls of the quartz-pyrite veins, but none has been seen in these veins with the exception of a single specimen in which adularia crystals occupy a vug in a quartz-pyrite vein. Only a little adularia penetrates the wall rock as a replacement mineral and where it does it is invariably associated with sericite. In specimens containing the most adularia sericite blades and rosettes replacing quartz commonly are separated from the quartz by thin selvages of adularia, and stringers cutting through the quartz contain sericite in the center and adularia along the margins. Probably sericite first replaced quartz and later selective replacement of sericite by adularia occurred along the quartz-sericite boundaries. This relationship occurs in some vein quartz as well as in original quartz grains, and together with the apparent association of adularia with chalcopyrite and molybdenite, it suggests that adularia was formed during the later stages of sulphide mineralization and quartz-sericite alteration.

Not only were some of the original minerals more susceptible than others to the quartz-sericite alteration, but the character of the alteration in the various minerals is distinctive. Quartz close to the veins has been partly replaced by coarse blades and rosettes of sericite. Also in orthoclase, the sericite occurs as coarse blades, but the blades are generally oriented along planes approximately at right angles as if controlled by the orthoclase structure, and invariably some silicification of the feldspar has taken place. In contrast, plagioclase and clay near quartz-pyrite veins have been replaced by extremely fine-grained sericite without any replacement by quartz. The original plagioclase can generally be recognized in completely altered rocks along the veins by mi-

crocrystalline aggregates of sericite having the shape of feldspar grains. The probable explanation for the lack of silicification in plagioclase is that both plagioclase and the clay developed in it are very susceptible to sericitization and were rapidly and completely replaced by sericite at the beginning of the quartz-sericite phase of alteration. The plagioclase having been sericitized, replacement by quartz was probably prevented. There is no definite evidence that quartz has replaced sericite anywhere in the Castle Dome area.

Biotite has been replaced by both sericite and quartz in the alteration borders along quartz-pyrite veins. The product is a pseudomorph composed of coarse sericite and quartz containing small aggregates of rutile. In some specimens the place of original biotite is indicated only by these rutile aggregates.

Rutile and leucoxene, developed from original sphene during the clay alteration, have likewise been recrystallized in the quartz-sericite borders along the veins to aggregates of larger grains. Commonly these aggregates also contain quartz and a few of them preserve the outlines of original euhedral sphene.

Quartz-pyrite veins in the diabase sills, as in the quartz monzonite, are bordered by zones of intense quartz-sericite alteration.

Areal Distribution of Alteration Phases.—Alteration and mineralization are almost confined to the quartz monzonite and the granite porphyry intruded into it. Figure 4 shows a generalized arrangement of the alteration phases into several zones. These zones are not concentric but rather extend across the quartz monzonite as bands trending in an east-northeast direction. The boundaries between them are gradational in a north-south direction. To the east, west, and south the alteration either ends at the margins of the quartz monzonite or is very weak beyond them, whereas to the north in the quartz monzonite the alteration decreases gradually until it becomes unrecognizable in the field.

The quartz-sericite phase of alteration is not confined within any well defined zone but occurs throughout the mineralized area along pyrite veins and veinlets cutting through both argillized and propylitized rock. However, a central area where pyrite mineralization and the associated quartz-sericite alteration are most intense can be clearly recognized. This is a zone passing through the summit of Porphyry Mountain and extending eastward nearly to the edge of the quartz monzonite and westward to the Gold Gulch fault (Fig. 4). The amount of pyrite and quartz-sericite alteration decreases gradually both to the north and to the south. Therefore, any northern or southern limit of this central zone is arbitrary and depends on the criteria chosen to define it. Because local intense sericitization and silicification occur along many faults, it is difficult to outline a single zone within which intense quartz-sericite alteration is confined, but examination in the field leaves no doubt that as Porphyry Mountain is approached either from the north or south the average intensity of quartz-sericite alteration increases greatly. Reasonably definite outlines of the central zone can be described only if the zone is defined as that area containing the greatest concentration of pyrite and the largest and most numerous quartz-pyrite veins as well as the greatest average intensity of quartz-sericite alteration. Thus defined, the central zone of generally strong quartz-sericite

alteration is arbitrarily made to correspond with the pyrite zone in hypogene mineralization. Its southern boundary is in the footwall of the ore body, its northern boundary is beneath the dump. To the east and west it ends abruptly near the margins of the quartz monzonite.

The most intense quartz-sericite alteration is entirely within the area where strong clay alteration occurs. Indeed, clay alteration can be seen within the central zone wherever the quartz monzonite is not completely sericitized and silicified. To the south, and probably beneath the dump to the north, quartz-pyrite veins are fewer and smaller, quartz-sericite alteration is generally less, and clay is the dominant alteration product. Farther from Porphyry Mountain the amount of clay as well as quartz-sericite alteration decreases, and in the marginal parts of the mineralized area to the north small veins with thin borders of quartz-sericite alteration occur in the propylitized rock containing no clay. Clearly the veins and the quartz-sericite alteration are imposed on the slightly earlier clay and propylitic phases of alteration, but all are apparently zoned about a center on Porphyry Mountain and undoubtedly all are stages in a single mineralization process.

A second smaller center of intense quartz-sericite alteration is on the south side of South Hill (Fig. 4). Strong alteration comparable to that in the mine area extends well down the north slope of the hill. It is separated from the strongly altered area on Porphyry Mountain by relatively weak clay and propylitic alteration which is associated with seemingly weak pyrite-chalcopyrite mineralization, whereas on South Hill copper mineralization is relatively strong as shown by three exploratory drill holes.

Faults controlled the variations in quartz-sericite alteration in many parts of the mineralized area. The intense alteration on South Hill (Fig. 4) was undoubtedly controlled by the fault zone separating the Pinal schist from quartz monzonite on the south side of the hill. The fault itself is mineralized and alteration decreases northward away from it. West of the mine, the Gold Gulch fault is the western boundary of strong alteration and mineralization, although the fault itself is mineralized and altered. West of it both alteration and mineralization are very weak. To the north, the East Branch of the Gold Gulch fault is the western boundary of the area in which mineralization and quartz-sericite alteration are pronounced, and the alteration extends farthest northward along this fault as well as along the group of north-northwest trending faults a few hundred feet to the east. Intense quartz-sericite alteration also occurs along the northeast-trending fault about 500 feet northwest of the Continental mine, and local intense sericitization is evident along the Dome fault in the southwestern part of Castle Dome mine and along many minor faults elsewhere in the mine. Probably many of these same faults also influenced the distribution of both clay and propylitic alteration but there is no direct indication that this is so.

Recrystallization of Biotite.—The original biotite that characterizes the quartz monzonite occurs as dark brown subhedral books, but within and south of the Castle Dome mine much of the original biotite is recrystallized to aggregates of small biotite plates, a few of which are intergrown with muscovite. Biotite aggregates are about the same size as the books (1/10 to 1/4 inch in di-

ameter), and they have about the same distribution in the rock. Invariably they are associated with small crystals of apatite, ilmenite, and sphene as are the books. In thin sections, various stages in the change from book to aggregate biotite can be observed. Such aggregates have a core composed of a remnant of the original book surrounded by numerous small biotite crystals having various orientations, and others are completely recrystallized. From a few biotite aggregates as centers, small trains of tiny biotite crystals extend as much as $\frac{1}{10}$ inch into the surrounding quartz and feldspars. In the quartz monzonite near some of its contacts with granite porphyry south of the mine aggregates of biotite can be seen, but fine grained biotite is scattered throughout the rock in veinlets that cut through all of the other minerals.

The composition of the biotite in books and in aggregates may vary slightly, but the optical properties of the two are essentially the same. Most of the original books contain needlelike rutile inclusions oriented in three directions at 60° in the basal plane (001). These inclusions have not been noted in the aggregate biotite seen in thin sections.

Aggregate biotite does not occur north of the mine and it increases in abundance toward the south. Near Gold Gulch and on South Hill biotite occurs only in the form of aggregates, although the biotite in the granodiorite and granite porphyry in that area occurs as thin plates and probably none has recrystallized.

The cause of the recrystallization of biotite is uncertain. At first it was thought that the recrystallization was an effect of hydrothermal alteration related to the copper mineralization and a record of its distribution was kept during the study of alteration in the mine. However, the distribution of aggregate biotite, showing the greatest recrystallization near the southern margin of the quartz monzonite, does not appear to conform to the zoning in the hypogene copper mineralization or the associated hydrothermal alteration although it does occur entirely within the mineralized area. Furthermore both types of biotite have been affected by propylitic, clay, and quartz-sericite phases of the alteration. Perhaps the recrystallization is a metamorphic effect produced by the intrusion of granite porphyry near the south margin of the quartz monzonite, or if the root of the quartz monzonite instrusion is south of Porphyry Mountain, as is likely, the recrystallization of biotite may be a deuteric change. S. G. Lasky [7] reports that in the Little Hatchet Mountains of New Mexico he found that such recrystallized biotite was a metamorphic effect, both endomorphic and exomorphic.

Supergene Clay Minerals.—Several clay minerals that appear to be of supergene origin are present in small amounts in the capping and in the chalcocite zone. These include halloysite, endellite, cimolite, and probably kaolinite. Halloysite, endellite and cimolite occur in small masses filling open fractures. They have been transported into cavities and clearly did not form by replacement of rock minerals. Some kaolinite is a product of weathering in the unmineralized quartz monzonite.

Chemical and Mineralogical Changes.—Chemical analyses of the fresh and altered quartz monzonite are shown in Table I. The samples representing

[7] Unpublished manuscript, U. S. Geol. Survey.

TABLE I.

CHEMICAL ANALYSES OF THE FRESH AND ALTERED QUARTZ MONZONITE.

Norman Davidson, Analyst.

Sample No.	1 Fresh	2 Fresh	3 Alt.	4 Alt.	5 Alt.
SiO_2	69.60	70.68	69.20	70.33	72.15
Al_2O_3	13.99	13.82	14.33	14.53	11.77
Fe_2O_3	1.82	2.03	1.03	.50	1.00
FeO	2.15	1.83	.99	1.03	.96
MgO	.86	.44	.73	.59	.43
CaO	2.12	1.61	.25	.32	.23
Na_2O	2.66	2.64	.72	1.02	.28
K_2O	4.56	4.48	5.53	6.10	3.46
$H_2O - 110°$ C	.14	.14	1.75	1.08	.02
$H_2O + 110°$ C	1.00	1.26	2.81	1.76	1.82
TiO_2	.62	.55	.66	.51	.43
P_2O_5	.23	.19	.13	.13	.08
MnO	.13	.11	.01	.02	.01
FeS_2	.02	.05	1.72	1.76	7.05
	99.90	99.83	99.86	99.68	99.69
Sp. gr. (bulk)	2.7	2.6	2.3	2.3	2.8
Sp. gr. (powder)	2.88	2.74	2.69	2.60	2.99

1 and 2. Unaltered quartz monzonite porphyry. ½ mile due north of Porphyry Mountain.
3. Altered quartz monzonite porphyry, clay phase.
4. Altered quartz monzonite porphyry, clay-sericite phase.
5. Altered quartz monzonite porphyry, quartz-sericite phase.

the fresh and altered rocks were necessarily collected from widely separated areas. Samples 1 and 2, representing fresh rock, were collected north of the dump about one-half mile from the area in the mine where the altered samples were taken. Although both samples appeared fresh, microscopic examination showed slight weathering of the plagioclase and the presence of some minerals of the propylitic phase. In order to appraise the accuracy of the sampling, two samples of the fresh rock, judged by inspection to be as similar in composition and texture as possible, were collected about 500 feet apart. To insure accurate sampling of such a coarse-grained rock, large samples were cut. These were crushed and reduced to convenient-sized pulps for chemical analysis by approved sampling methods.

The two analyses agree very well in those oxides which represent the essential constitutents of the rock. The differences between the two are believed to represent actual differences in composition rather than errors in sampling and analysis. In the tables that follow an average of the two analyses is used to represent the composition of the fresh rock.

Table II is an attempt to recast the analyses to show the approximate mineral composition of the fresh and altered rocks. Although in detail the computed mineral composition is not strictly accurate, the major constituents conform with the general mineral composition observed during the study of about 125 thin sections. The boldest assumption involved in the construction of the table is that the original composition of all the samples before alteration was

TABLE II.

RECAST OF THE CHEMICAL ANALYSES TO SHOW APPROXIMATE MINERAL COMPOSITION OF THE FRESH AND ALTERED QUARTZ MONZONITE.

Sample No.	1 and 2 Fresh	3 Alt.	4 Alt.	5 Alt.
Quartz	32.66	35.03	36.23	57.10
Orthoclase	22.29	25.68 [b]	25.68 [b]	—
Albite	22.55	6.09	8.69	2.38
Anorthite	7.03	.49	.85	—
Biotite	7.27	—	—	—
Apatite	.50	.28	.28	.17
Ilmenite	.61	—	—	—
Sphene	.63	—	—	—
Magnetite	2.67	—	—	—
Kaolinite	3.01 [a]	—	—	—
Bleached biotite	—	3.83	3.08	—
Rutile	—	.66	.51	.43
Beidellite	—	16.92	8.70	.21
Sericite	—	6.35 [c]	11.86 [c]	29.33
Limonite	—	1.26	.61	1.23
Pyrite	.03	1.72	1.76	7.05

[a] Excess alumina computed as kaolinite, includes minor amounts of other alteration minerals.
[b] Orthoclase assumed to remain unaltered in these phases. Percentage was computed on basis of equal weights in equivalent volumes of the fresh and altered rocks. (See Table IV.)
[c] Hydrous mica computed as sericite.

the same. This is obviously only approximately true. Some very minor constituents were ignored, and the exact composition of many of the alteration products is uncertain. For example, the nature of the chemical changes in the bleaching of biotite is not known, nor is the degree of base exchange in the clays. The amount of orthoclase in samples 3 and 4 is based on the assumption that in these phases all the orthoclase remains unaltered, that is, the weight of orthoclase in equivalent volumes of the fresh and argillized rock is the same

TABLE III.

SHOWING THE WEIGHT IN GRAMS OF EACH OXIDE IN 1 CUBIC CENTIMETER OF THE FRESH AND ALTERED QUARTZ MONZONITE.

Sample No.	1 and 2 Fresh	3 Alt.	4 Alt.	5 Alt.
SiO_2	1.858	1.592	1.617	2.020
Al_2O_3	.368	.329	.334	.330
Fe_2O_3	.051	.024	.012	.028
FeO	.053	.023	.024	.027
MgO	.017	.017	.014	.012
CaO	.050	.006	.007	.006
Na_2O	.071	.017	.023	.008
K_2O	.119	.127	.140	.097
H_2O $-110°$	.004	.040	.025	.001
H_2O $+110°$	.030	.065	.041	.051
TiO_2	.016	.015	.012	.012
P_2O_5	.006	.003	.003	.002
MnO	.003	—	—	—
FeS_2	.001	.040	.041	.197

(see Table IV). The study of thin sections shows ample evidence to justify this assumption.

The gains and losses of the constituents in equivalent volumes of the fresh and altered rocks can be seen in Table III, which shows the computed weights of the various constituents in one cubic centimeter of rock. Although the values for samples 3 and 4 are not entirely accurate because of the difficulties encountered in determining the bulk specific gravities of these highly argillized rocks, they are considered sufficiently reliable to illustrate the general changes in composition.

Table IV shows the weights of the mineral constituents in one cubic centimeter of rock. In studying the chemical and mineralogical changes illustrated by these two tables the reader should realize that the relationships between the samples are not necessarily one of progressive change from fresh quartz monzonite through an argillized phase, as represented by No. 3, and an intermediate phase, represented by No. 4, to a rock almost completely replaced by quartz and sericite. The intermediate sample (No. 4) was probably never as completely argillized as No. 3; and the higher plagioclase content should not be construed to indicate that plagioclase has been introduced, but rather that the plagioclase in this sample is not as completely altered as that in No. 3.

In the alteration of the fresh rock to the clay phase, only plagioclase and biotite suffered noteworthy change. The decrease in silica (Table III) represents an actual leaching accompanying the replacement of oligoclase by clay. Quartz (Table IV) decreases slightly; but since microscopic study shows that quartz is rarely replaced in the clay phase, the decrease shown by sample 3 may be at least partly due to a primary difference in composition. Magnesia remains constant, whereas lime, soda and alumina decrease due to the de-

TABLE IV.

SHOWING THE WEIGHT IN GRAMS OF EACH MINERAL CONSTITUENT IN 1 CUBIC CENTIMETER OF THE FRESH AND ALTERED QUARTZ MONZONITE.

Sample No.	1 and 2 Fresh	3 Alt.	4 Alt.	5 Alt.
Quartz	.865	.806	.833	1.599
Orthoclase	.591	.591 [a]	.591 [a]	—
Albite	.597	.140	.200	.067
Anorthite	.186	.011	.019	—
Biotite	.192	—	—	—
Apatite	.013	.006	.006	.005
Ilmenite	.016	—	—	—
Sphene	.017	—	—	—
Magnetite	.070	—	—	—
Kaolinite	.080	—	—	—
Bleached biotite	—	.088	.071	—
Rutile	—	.015	.012	.012
Beidellite	—	.389	.200	.006
Sericite	—	.146 [b]	.273 [b]	.821
Limonite	—	.029	.015	.034
Pyrite	.001	.040	.041	.197

[a] All orthoclase assumed to remain unaltered in these phases.
[b] Hydrous mica computed as sericite.

struction of plagioclase. Both ferric and ferrous iron are leached. Potash is added and appears as sericite and hydrous mica associated with the clay. It is highest in sample 4 in which the plagioclase contains a higher ratio of sericite to clay. Total water reaches a maximum in the most highly argillized rock and decreases as the proportion of sericite to clay increases. Titanium oxide remains virtually constant in the change from primary ilmenite and sphene to rutile and leucoxene in the altered rock. About half of the apatite is leached at this stage of alteration. The residual plagioclase becomes progressively more sodic as the degree of alteration increases.

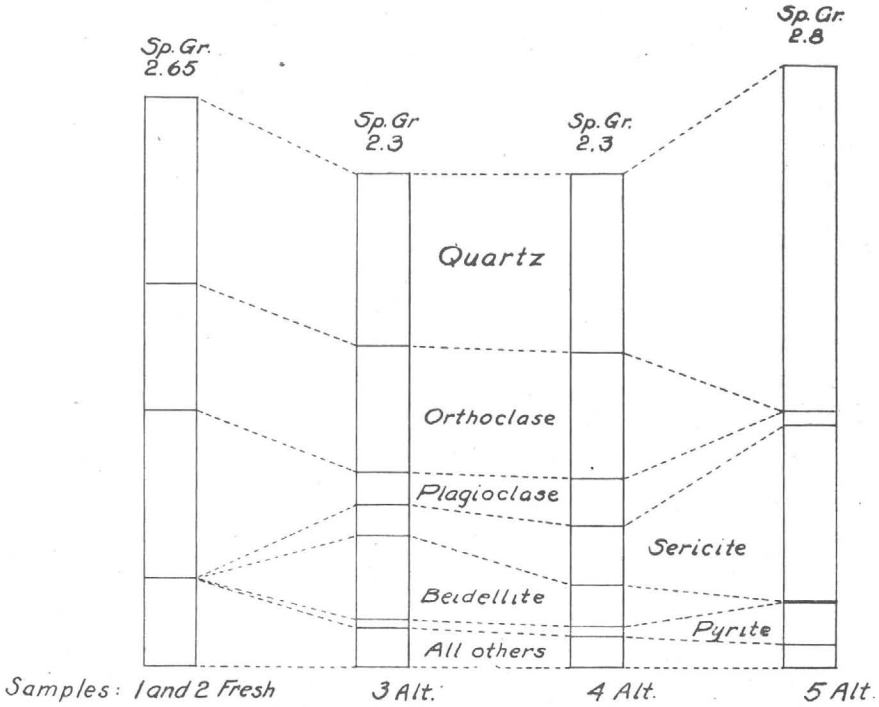


FIG. 5. Diagram showing mineralogic changes in the alteration of 1 cubic centimeter of quartz monzonite.

In the final stage of quartz-sericite alteration, represented by sample 5, all the original minerals of the rock are destroyed except quartz which suffers only a minor degree of replacement by sericite. Silica increases mainly by the introduction of vein quartz. Alumina remains nearly constant after the plagioclase is destroyed. Water expelled below 110° C. decreases to a minimum with complete substitution of clay by quartz and sericite. Potash decreases when orthoclase is replaced, but even after complete replacement it is only a little lower than in the fresh rock. The relatively high ferric iron content of the altered rocks, especially in the quartz-sericite phase, is due to supergene products, mainly limonite, resulting from the oxidation of pyrite. Sample 5

contains a small excess of lime, magnesia and ferrous iron which is not accounted for by any mineral recognized in thin sections of the rock. The changes in mineral composition from fresh quartz monzonite to the altered phases in equivalent volumes of rock are illustrated in Fig. 5.

CHARACTER OF THE MINERALIZING SOLUTIONS.

What little can be said concerning the character of the mineralizing solutions must be inferred from the effects which the solutions produced in the rocks within the present range of observation, approximately 900 feet in vertical extent. The solutions apparently were rich in silica, iron and sulphur and also contained copper, molybdenum, zinc, lead, barium and probably a little phosphoric acid and carbon dioxide. Most of the sulphur was deposited as metallic sulphides, but some barite formed during the late stages of mineralization. The minerals produced in the altered host rock are among those generally considered to form in at least a mildly alkalic environment. Although the solutions may be assumed to have been acid nearer their source, no evidence has been found to suggest that they were still acid when they reached the rocks now exposed.

Whether or not they carried potash from their magma source is debatable. Along the veins and in the most intensely altered parts they deposited quartz and pyrite and altered the rock minerals to quartz and sericite. Here potash was removed to some extent. The solutions, that penetrated farther into the wall rock adjacent to the veins and probably also the rock above the most intensely altered zone, were so changed in character that their ability to form sericite was largely spent. They continued to leach soda, lime, iron, silica and alumina and altered the plagioclase to clay minerals. Some potash was added to form the sericite and hydrous mica disseminated in the clay. If we assume that silicification and sericitization are more intense at depth, the potash added in the clay zone could easily be accounted for as having been leached from deeper rocks.

The solutions that soaked farthest out from the main paths of circulation deposited a little pyrite and carbonates. They may also have deposited some magnesia, lime, potash and iron to form the alteration minerals characteristic of the propylitic zone; at least they were sufficiently concentrated in these bases to prevent further leaching.

U. S. Geological Survey,
Washington, D. C.,
Oct. 25, 1946.

TRIP THRU YERINGTON PIT
WITH JIM WILSON 8/23/55

LOWEST BENCH 4300
Brec. in well min. section
on NE side of pit.

ON NEXT BENCH ABOVE 4325
ON APPROX. STRIKE OF BRECCIA
BRECCIA FRAGMENTS - BREC. ROCK
CEMENTED BY MINERAL — IN
MUCK PILE BEING SHOVELLED —
GRADE OF ORE REPORTED
ABOUT 1%

ON 4350 RUBBLE LIKE BRECCIA
4-6' WIDE, IN NE SIDE
OF PIT STRIKE N45-60°W
DIP STEEP. DOES NOT
APPEAR TO BE ON STRIKE
OF BRECCIA ZONES SEEN ON
4300 + 4325 BENCHES.

96437

chlorite

$H_8(Mg\ Fe)_5\ Al\ (SiO_6)_3$

epidote

$Ca_2(Al\ Fe)_3\ (OH)(SiO_4)_3$

COPY

THE ANACONDA COMPANY

151 S. Tucson Blvd. — Room 221

Tucson, Arizona

Geological Department
Southwest Office

November 13, 1962

Mr. Roland B. Mulchay, Asst. Chief Geologist
The Anaconda Company
809 Kearns Building
Salt Lake City 1, Utah

Dear Mr. Mulchay:

On November 9, 1962, Mr. Jerry Y. Bell, consulting geologist from Newport Beach, California, called our office in regards to the Winkler claim groups, north of Safford, Graham County, Arizona. This is the property that was visited by Gerald E. Rupp and me on June 27 and 28, 1962, and described in my letter to you of July 6, 1962.

Mr. Bell stated that he represented Mr. Navor Proctor, attorney in Globe, Arizona, who has obtained an option on the 236 and 173 claims groups outlined on the U.S.G.S. topographic map accompanying my July 6 letter. Proctor reportedly has reached an agreement with Winkler and the numerous other owners of the property, and he and Bell are offering the following terms:

(1) Proctor will guarantee the legality of all 409 claims, as to proper location monuments, pits, and assessment work to date.

(2) Up to five years will be permitted for an examination of the area, which would include any geophysical and geological surveys, drilling, or other exploration work deemed necessary; during this period, the examining company will only be responsible for performing the annual assessment work on the property.

(3) At the end of the required examination period, the interested company may purchase any of the claims at the rate of $8000. per claim, or retain the property on payment of 5% royalty of net smelter returns.

(4) Bell, as promoter of the property, would like 1% royalty of net smelter returns, for the life of any mine developed; he commented that he might accept a cash payment instead.

No additional development or exploration has been reportedly done on the claims since our visit last June. The San Juan Mine property is still in litigation, and legally not available for consideration.

Bell claims that the Winkler property has a good potential for containing a copper sulfide concentration due to the intersection of a shear zone between the Phelps Dodge-Kennecott properties, and a shear zone entirely on the Winkler claims. He did not explain the basis for this assumption of conditions below a minimum of probably 600 feet of gravel cover.

The terms of the agreement permitting additional exploration on the Winkler property, as described by Bell, are reasonable. If the owners are actually interested in selling the property, a satisfactory option involving a final price should be negogiable. As concluded in my letter of July 6, a geophysical survey of the area would be of interest on the basis of the proximity to the Phelps Dodge and Kennecott properties.

Bell was told that we would inform him of our possible interest in the terms described. He is leaving for the Fiji Islands to study gold placers in the near future, and would appreciate our decision at the earliest convenience.

Yours very truly,

G. A. Barber

G. A. Barber

GAB:je

NOV 14 1962

COPY

THE ANACONDA COMPANY

151 S. Tucson Blvd. — Room 221

Tucson, Arizona

Geological Department
Southwest Office

November 13, 1962

Mr. Roland B. Mulchay, Asst. Chief Geologist
The Anaconda Company
809 Kearns Building
Salt Lake City 1, Utah

Dear Mr. Mulchay:

On November 9, 1962, Mr. Jerry Y. Bell, consulting geologist from Newport Beach, California, called our office in regards to the Winkler claim groups, north of Safford, Graham County, Arizona. This is the property that was visited by Gerald E. Rupp and me on June 27 and 28, 1962, and described in my letter to you of July 6, 1962.

Mr. Bell stated that he represented Mr. Navor Proctor, attorney in Globe, Arizona, who has obtained an option on the 236 and 173 claims groups outlined on the U.S.G.S. topographic map accompanying my July 6 letter. Proctor reportedly has reached an agreement with Winkler and the numerous other owners of the property, and he and Bell are offering the following terms:

(1) Proctor will guarantee the legality of all 409 claims, as to proper location monuments, pits, and assessment work to date.

(2) Up to five years will be permitted for an examination of the area, which would include any geophysical and geological surveys, drilling, or other exploration work deemed necessary; during this period, the examining company will only be responsible for performing the annual assessment work on the property.

(3) At the end of the required examination period, the interested company may purchase any of the claims at the rate of $8000. per claim, or retain the property on payment of 5% royalty of net smelter returns.

(4) Bell, as promoter of the property, would like 1% royalty of net smelter returns, for the life of any mine developed; he commented that he might accept a cash payment instead.

No additional development or exploration has been reportedly done on the claims since our visit last June. The San Juan Mine property is still in litigation, and legally not available for consideration.

Bell claims that the Winkler property has a good potential for containing a copper sulfide concentration due to the intersection of a shear zone between the Phelps Dodge-Kennecott properties, and a shear zone entirely on the Winkler claims. He did not explain the basis for this assumption of conditions below a minimum of probably 600 feet of gravel cover.

The terms of the agreement permitting additional exploration on the Winkler property, as described by Bell, are reasonable. If the owners are actually interested in selling the property, a satisfactory option involving a final price should be negogiable. As concluded in my letter of July 6, a geophysical survey of the area would be of interest on the basis of the proximity to the Phelps Dodge and Kennecott properties.

Bell was told that we would inform him of our possible interest in the terms described. He is leaving for the Fiji Islands to study gold placers in the near future, and would appreciate our decision at the earliest convenience.

Yours very truly,

G. A. Barber

G. A. Barber

GAB:je

FORM 1168

MEMO

To RBH

Date 3/30/62 Time

Phone from Alan Pinger

To

Place

Subject ~~Leaching prospect S. of~~ Page.

Present

Wants as leaching consultant for property S. of Page, Ariz.

5:30 PM – Called Jay Gould from home.

he recommends Frank Honnegar or Harvard Jackey of his staff – Also Ben Cody of Phoenix.

any arrangements must be made thru Hillan

H.P. Robinson →

6 PM Called Pinger – he will advise earlier principals,

FORM 1168

MEMO

To A. Pinger
Date 4/26/62 Time 11 AM
Phone from
To
Place
Subject oxide Cu consultant.
Present

Zontelli Bros. Ironton, Minn.

20 mi S. of Page, Ariz.

Thurmond from Socorro. —

No plant. 40-50,000 ft. of drilling.

11:15 AM called Millan. Not there. — Informed Pinger I would call tomorrow.

4/27/62 Millan says they will run samples in test plant for $50.00 — Will have Monnegan do work — Does not want them (Monn. or Jackey to go to property) Send 100-200 lbs. by truck freight.

A E Millan.
Youngton
Greyhound
Ringsby. ✓

He sent letter to Dyer with Youngton options — believes he has enough ground to make drilling to test possibilities feasible.

Millan has been in Ariz. on Duval work

12:05 Called A. Pinger. He will inform Minn. group.

L 14370

Mrs Alice

FORM 1168 6-8-54 5M

MEMO

To RBM

Date 2/14/61 Time 4:10 PM

Phone from Fulmer

To

Place

Subject BeO assays.

Present

		Spect. % BeO	wet % BeO.	# 52 BeO.	# 50 BeO.
Aquamarine group Yavapai Co. Ariz.	33L86	0.10			
	A	0.09.			
Blue Bell Group Yavapai Co, Ariz.	56102	.09			
Bismith Lode Group Grant Co., N.M.	8980	.11		0.09	
	7	Nil		.06	
Empire Star prospect Juab Co. Utah	1046	.12		.03.	
Morgan Prospect Summit County, Ut.	2784-1	.12			

Telephone 363-3302

Hand Sample Serial 3083-3085

ASSAY REPORT

UNION ASSAY OFFICE, Inc.

W. C. WANLASS, President
L. G. HALL, Vice President
G. P. WILLIAMS, Treasurer
LILY M. HOTTINGER, Secretary
P. O. Box 1528
Salt Lake City 10, Utah

Mine Lory M. Free
1709 North 580 East
Provo, Utah

RESULTS PER TON OF 2000 POUNDS

Feb. 18, 1965

NUMBER	GOLD Ozs. per Ton	SILVER Ozs. per Ton	LEAD Wet on Ore	COPPER Per Cent	INSOL. Per Cent	ZINC Per Cent	SULPHUR Per Cent	IRON Per Cent	LIME Per Cent	Per Cent	Per Cent
Papago #1	Trace	7.8		1.37							
Papago #2	Trace	2.1		0.453							
Papago #3	Trace	6.2		1.42							

White Wing, Prospect
Pima County, Ariz
Grab of dump

Remarks

Charges $ 12.00

W. C. Wanlass

Date 2/1/65

	Au	Ag	Cu
Pappago 1	0.005	10.0	1.80
Trove #1	0.04	1.6	6.86
3			

THE ANACONDA COMPANY - EXPLORATION DEPARTMENT

RECAPITULATION OF PAYMENTS REQUIRED TO BE MADE ON LEASE AND OPTION AGREEMENTS IN ORDER TO MAINTAIN THE CONTRACTS IN FULL FORCE AND EFFECT

Properties & Locations	Payments made prior to 1957	* 1957	1958	1959	1960	1961	1962	Subsequent to 1962	TOTAL OPTION PRICE
Hall Molybdenum Property, Nye Co., Nevada	$	$ 3,500.00	$ 6,000.00	$ 9,500.00	$12,000.00	$ 5,000.00	June 1, 1962 $100,000.00	$ 364,000.00	$ 500,000.00
MacArthur Group, Lyon County, Nevada	CANCELLED		12,000.00	18,000.00	27,500.00	27,500.00	27,500.00	137,500.00	250,000.00
**Grey Day & Magpie Claims, Lyon Co., Nevada	CANCELLED								5,000.00
Fortuna de Cobre Claims, Sonora, Mexico	?		50,000.00	50,000.00	50,000.00	50,000.00	50,000.00	50,000.00	300,000.00
Arizona Claims 1-8, Pinal Co., Arizona		120.00	120.00	120.00	120.00	120.00	120.00		
Arizona Claims 9-12, Pinal Co., Arizona		60.00	60.00	60.00	60.00	60.00	60.00		
Santa Rosa Claims, Inyo Co., California	24,079.37	# 3,464.50	5,000.00	5,000.00	5,000.00	10,000.00	15,000.00	182,456.13	250,000.00
****Victoria Claims, Elko Co., Nevada	25,000.00								75,000.00
Northern Pacific Property, King Co., Wash.	CANCELLED ?		750.00	1,000.00	2,500.00	4,500.00	5,000.00	96,250.00	110,000.00
Rainy Claims, King Co., Washington	" ?		15,000.00	25,000.00	25,000.00	25,000.00	25,000.00	185,000.00	300,000.00
Western States Copper & U. Prop., King Co., Washington	" ?		50,000.00	50,000.00	50,000.00				150,000.00
H. & R. Co's. Interest, King Co., Wash.	" ?		57,500.00						57,500.00
United Cascade Claims, King Co., Wash.	" ?		10,000.00	15,000.00	20,000.00	25,000.00	30,000.00	1,400,000.00	1,500,000.00
Leo Wall Prop. (Wooley), Pinal Co., Ariz.	CANCELLED	1,650.00	1,800.00	25,300.00	25,000.00	25,000.00	25,000.00	296,250.00	400,000.00
A. L. Culver Prop., Otero Co., New Mexico	1,950.00	1,800.00	1,800.00	1,800.00	1,800.00	1,800.00	1,800.00	27,250.00	40,000.00
***Pacific States Cast Iron Pipe Company, Albany County, Wyoming									
Collins & Bartlett (Shanton), Albany County, Wyoming	CANCELLED 2,000.00	18,000.00	20,000.00	20,000.00	20,000.00	20,000.00			100,000.00
CANCELLED Homan Arnold Property, Otero Co., New Mex.	1,250.00	8,400.00	18,000.00	24,000.00	24,000.00	24,000.00	24,000.00	26,350.00	150,000.00
— " Leo & Iola Duriez Prop., " " "	600.00	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00	2,200.00	10,000.00

* Includes payments made during 1957 as well as those yet to be made.
** Requires Royalty Payments only.
*** Requires only payments for taxes, rentals, etc.
**** $25,000.00 was paid on 11-1-55; balance of $50,000.00 is payable in the form of 5% royalty only.
\# $2,057.86 of this amount was paid as royalty; the balance of $1,406.64 will be paid by check.

Total royalty July 1 1956 – June 30, 1957 = 3541.06
1957?
1458.94
5000.00
Paid July 24 57

Ida separate to leg board — Pres of Univ
Geol Surv
Geol Dept.

Board in Univ.
Accounting.

Ariz. under Univ.

Under sympathetic head has advantages
only convince head of Univ of needs, then
he gets money in over-all budget —
less expense and time needed by B of H head?

Accounting then over by Univ.

Close cooperation with University aids in
programming, (one from old practice, leads
to employment of professors during summer
supplementing pay scale)

If head of Univ. not sympathetic, might be
difficult. His experience of Idaho under direct
legislative appropriations and board control (head of Univ.,
head of local USGS, Geology head and two others) was
equally satisfactory. (Appeared that more of director's
time was taken on political activity, and some
of departments' time on accounting work). In effect,
under both systems, scope of work and direction
activities take was left up to director. He had
both authority and support of controlling heads.

Says Kansas is also set up in University.

Does not believe a board of business men
might be as easily convinced of needs as Univ. head
or board composed of people with mineral background.

CALL TO J. D. FORRESTER Tucson 2PM 1/30/59

SUMMARY
SE AREA.
UPPER

		TONS	CU		MO.	
SECT.	2600	2,580,000	1.02	2,631,600	0.073	18 8,340
	2400	5,710,000	0.86	4,910,600	0.075	42 8,450
	2000	4,320,000	1.67	7,214,400	0.058	25,0560
	1600	2,946,800	1.74	5,127,432	0.021	6,1880
	1200	8,252,000	1.11	9,159,720	0.050	41.2600
	800	743,300	0.88	654,104	0.030	22 2299.
	600	1,080,000	3.07	3,315,600	0.062	66 960.
DDHs. 629-630		7,148,000	1.55	11,079,400	0.032	228736
		32,780,100		44,092,856		

1.34% Cu

0.051 Mo

SE AREA
LOWER

SECT.	2600	966,700	1.25	0.160
	2400	3,545,000	1.49	0.044
		1,545,000	1.06	0.061
		3,420,000	0.62	0.012
	2000	6,800,000	0.78	0.076
		7,600,000	0.81	0.037
		4,800,000	0.85	0.004
	1600	8,666,800	1.00	0.060
		7,020,800	1.04	0.115
	1200	44,364,300	0.94	0.058

TOTALS

SE UPPER	32,780,100	1.34	0.051
LOWER	44,364,300	0.94	0.058
	77,144,400	1.11	0.055

3/11/64

SUMMARY

UPPER BLOCK

DDHs 629, 652 and 630

Sect. 2000

①	3,444,000 T. @	1.7 Cu	0.033 Mo
②	3,704,000	1.4	0.032
	7,148,000	1.55 Cu	0.032 Mo.

'Try to get Eisenhower.' 3/19/64

4 drills, on development at SE pit.
Rotary down holes.

3 " on exploration.

Drap. Co. at Twin Buttes.

6 Drills at E. Helvetia

50 holes development — not deeper than pit ~~deepest~~ slopes
at various points

Get Knabel's pit outline, see on aerial photos
to lay out drill locations.

Review program with Knabel, send print to
RBN — Perry for general discussion

Tonnage exp 1.5 d/13. CEW
3.0 Navin.

20,000 Tons
300
14
6,000,000
84,000,000
5
420,000,000 profit/year

Perry mea 75,000, ~~on~~ C 0.78
for Banner calcs.
down to 31st lift or
2074 el?

NW AREA

6/15/64

SUMMARY

SECT. BLOCK	TONS (THOUSANDS)	CU		MO	
			4 4 4 3		4 4 4 3
1200NW	3,560	0.68	2,420,000	0.026	92.56
800	2,760	0.71	1,959,600	0.022	60.72
600	2,822	0.70	1,975,400	0.021	59.26
400	5,650	0.63	3,559,500	0.035	197.75
200NW	6,580	0.58	3,816,400	0.033	217.14
BASELINE	7,093	0.61	4,326,730	0.032	226.97
200SE	9,856	0.74	7,293,440	0.038	374.53
400SE	6,140	0.68	4,175,200	0.041	251.74
	44,461,000 T.		29,526,270		1480.67
		@ 0.66		0.033	

```
 9856
   74
-------
 39424
68992
-------
7,293,44
```

```
 9856
 .038
-------
 78848
29568
-------
374.528
```

```
 2822
    7
-------
19754
```

```
 2822
 0.21
-------
 2822
5644
-------
59.262
```

```
                .664
44,461 | 29,525,270
         26 6766
         -------
          28 4867
          26 6766
          -------
           181,010
           177844
```

```
              .033
44461 | 1480.67
        133383
        ------
         146840
         133361
```

3/10/64

NW

SUMMARY

SEC.	TONS	CU	MO
1200 NW	3,560,000T @	0.68	0.026
800 NW	2,760,000	0.71	0.022
600 NW	2,822,000	0.70	0.021
400 NW	5,650,000	0.63	0.035
200 NW	6,580,000	0.58	0.033
BASELINE	7,093,000	0.61	0.032
200 SE	9,856,000	0.74	0.038
400 SE	6,140,000	0.68	0.041

CALC. 3/10/64

3,560,000	0.68	2,420,000	0.026	92.5600
2760,000	0.71	1,959,600	0.022	60.72
5 650,000	0.63	3,559,500	0.035	197.75
6 580,000	0.58	3,816,400	0.033	217.14
7.093 000	0.61	4,326730	0.032	226.97
6,140,000	0.68	4,175200	0.041	251.74
31,783,000		20,257,430		1046.88

0.64 0.033

```
                  0.64
31,783,000 | 20,257,430.0
             19069800 0
             118,763000
             126932000
```

```
                  .0.033
31,783,000 | 1046.8880.00
             953 49000
             9,339,0000
```

SECT 400SE

		C_u	M_o
646	949-1332	383 - 0.83	0.025
607	638-1573	935 - 0.67	0.038
638	603-1128	525 - 0.59	0.059
		1843 0.68	0.041
		614	

3110164

383 × 0.83 319.89
935 × 0.67 626.45
525 × 0.59 309.75
1843) 1254.09 (.68
11058
14829
14744

×0.025 9.575
0.038 35.530
.059 30.975
76.080

.041
1843) 76.080
7372
2360

$$\frac{614 \times \overset{50}{\cancel{600}} \times 200}{\cancel{12}} = 6{,}140{,}000 \text{ T.}$$

SECT. 200 SE 3/15/64

		Cu	Mo
279	630-1207 = 577'	0.90	
663	518-1409 = 885	0.66	0.041
669			

Assume 705 − 1576 = 871 ± 0.65 0.028

705
871

366
2699
875

0.74
4 | 2.95
.74

0.044
3 | 1.113
.038

Between 646 651
646 651 383' — 0.83

651 349 — 0.66

732
366

149
.74

0.025
0.064
.089
.044

577
885
871
366
4 | 2699
675

56
675 × 880 × 200 = 9,856,000 ft.
12

56
200
11200
880
896000
896000
9,856000

0.74 Cu

0.038 Mo.

SECT. * BASELINE 3/10/64

			Cu	
651	975 - 1324	= 349'	- 0.66	0.064 M_o
188	700 - 1520	= 820'	- 0.65	0.017
639	521 - 740 = 219 982 - 1323 - 341	560	- 0.57	0.048
609	741 - 1141	= 400	- 0.52	± 0.015
		2129	- 0.61	0.032
		532'		

349	0.66	230.34	0.064	22.336
820	0.65	533.00	0.017	13.940
560	0.57	319.20	0.048	26.880
400	0.52	208.00	.015	6.000
	2129)	1290.54 (.606	2129)	69.156 (0.032
		12774		6387
		13140		5286
				4256
				1030

$$\frac{532 \times 800 \times 200}{12} = 7,093,300 \text{ T.}$$

532
160000
3192
532
12) 85120000
7,093,333

SECT. 200 NW 3/10/64

			Cu	
655	604 - 1456 =	852' —	0.63	0.040
294	936 - 1212 =	276' —	0.44	.015
		1128	0.58	
		564		

852 x 0.63 536.76

276 x 0.44 121.44

1128) 658.20 (.583
5640
9420
9.024
3960

0.04 34.08

0.015 4.14

1128) 38.18 (0.033
3384
4340

$$\frac{564 \times 700 \times 200}{12} = 6,580,000 \text{ T.}$$

@ 0.58 Cu
0.033 Mo

47
140000
1880000
47
6,580,000

Sec. 400 NW 3/10/64

		Cu	
636	905 - 1466 = 561'	0.73	0.023 Mo
606	661 - 1471 = 810'	0.56	.039
645	676 - 750 = 74 838 - 856 = 18 1047 - 1278 = 231 } = 323'	0.63	.045
	1694	0.63	0.035
	565		

4	2.40						0.035
1	1.09						
13	8.84	561 × 0.73	409.53	0.023	12.903
18	12.33 .63	810 × 0.56	453.60	0.039	31.590
	1268	323 × 0.63	203.49	0.045	14.535
	50 54	1694	1066.59 .63	1694	59.028
			10164		5082
			5019		8208
			5082		8420

68
13
204
68
884

$$\frac{565 \times \overset{50}{\cancel{600}} \times 200}{\cancel{12}} = 5{,}650{,}000\text{T.}$$

5650,000

SECT. 600 N.W.

3/14/64

ASSUME BETWEEN				
HOLES	636	561'	0.73	0.023
	644	434'	0.83	0.019
		995	0.78	0.020
		500'		

ASSUMED SECT. BET. 636-644		500'	0.78	0.020
666		244'	0.75	0.025
670	ASSUME	250	0.50	0.020
		994		
		332	0.70	0.021

42.5
200
8500.0

332
8500
16600
2656
2,822,000

$$\frac{\overset{20}{\cancel{332}} \times \overset{42.5}{\cancel{510}} \times 20.0}{12} = 2,822,000 \text{ T}$$

C

ASSUMED. ? 0.70 Cu — 0.021

100	0.82	0.021
25	0.50	0.021
16	0.58	0.020
103	0.73	0.032
244'		

Sect	Upper	Lower
1200	1346	2456
1600	± 1100	1995
2000	1557	2888
2400	1469	2281
2600	1005	1836

SEC. 800 NW

3/10/64

		Cu	Mo
644	777 - 1211 =	434 - 0.83	0.019
612	741 - 1057 =	316 - 0.54	0.027
		750 .71	0.022
		275	

434 x .83 360.22

316 x .54 170.64

750) 530.86 (.708

5250

5860

0.019

0.027

8.246

8.532

750) 16.778 (0.022

1500

1778

$$\frac{275 \times 400 \times 300}{12} = 2,760,000 \text{ T.}$$

23

120000

460000

23

2,760,000

SECT. 1200 NW

3/10/64

		Cu	Mo
611	775 - 1220 = 445'	0.68	0.026

$$\frac{445 \times \cancel{250}^{20} \times 400}{\cancel{12}} = 3,560,000 \text{ T.}$$

445
8000
3,560,000