CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
3550 N. Central Ave, 2nd floor
Phoenix, AZ, 85012
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

# A GEOLOGIC EVALUATION OF THE SQUAW PEAK PORPHYRY COPPER DEPOSIT, YAVAPAI COUNTY, ARIZONA

Submitted by:
R. Roe
July, 1974

## Location and Geography

The Squaw Peak deposit is located approximately six miles south of Camp Verde, Yavapai County, Arizona. Camp Verde is approximately 35 airline miles east of Prescott, Arizona and 75 airline miles north of Phoenix. The area studied covers parts or all of Sections 24, 25, and 36, Township 13 North, Range 4 East; Sections 19, 20, 29, 30, 31, and 32, Township 13 North, Range 5 East; Section 36, Township 12½ North, Range 4 East; and Section 1, Township 12 North, Range 4 East; in addition to land of unestablished status within the Prescott National Forest. The area is contained in the Camp Verde, Horner Mountain, Arnold Mesa, and Middle Verde 7.5 minute series topographic maps.

The Squaw Peak deposit may be reached from Camp Verde by traveling south on Main Street to the Salt Mine Road, then west and south on the Salt Mine Road for approximately eight miles to the Squaw Peak Mine road. The Squaw Peak Mine road is one and one-half miles long and terminates in a network of dirt roads in the vicinity of the old Squaw Peak Mine.

The Squaw Peak area is on the eastern flanks of the Black Hills, a northwest-trending range which bounds the Verde River Valley on the southwest and rises 2,000 to 3,000 feet above the valley floor in the Squaw Peak area. Squaw Peak is the highest point in the southern Black Hills and reaches an elevation of 6525 feet. The Black Hills are dissected by steep canyons and washes which drain eastward to the Verde River.

## Exploration History

Mining claims were located on the Squaw Peak prospect as early as 1883. Serious interest in the property began in 1916, when the Squaw Peak Mining Company was incorporated with the purpose of financing an exploration program at what would be known as the Squaw Peak Mine. No significant exploration was undertaken until World War II, when underground drifts and some diamond drilling were completed with the help of a $20,000 federal government loan.

Underground workings at the Squaw Peak Mine constitute about 4160 feet of drifts and about 200 feet of raises. Two levels of drifts, known as the Main Tunnel level and the Haulage Tunnel level, were driven at elevations of 4150 feet and 3850 feet, respectively. The Main Tunnel level consists of 2175 feet of drifts, and the Haulage Tunnel is 2050 feet long. Only about 500 feet of the Main Tunnel are now accessible.

The first recorded ore shipments were in 1944. Production at the Squaw Peak Mine during 1944, 1945, and 1946 amounted to 5.40 tons of concentrate containing 98.82 % molybdenite and 36.03 tons of concentrate containing 22.85% copper, 1.92 ounces per ton of siver, and 0.016 ounces per ton of gold. These concentrates were produced from approximately one thousand tons of ore, most of which was removed from raises on the Main Tunnel level.

Only minor exploratory drilling was undertaken from 1947 to 1967. Intermountain Exploration Company drilled two diamond drill holes totaling 601 feet from the Main Tunnel level about 450 feet from the portal during June and July, 1961. In August, 1963 Boyles Brothers Drilling Company completed a 723.6-foot vertical hole from the surface northeast of the mine. During March and April, 1964 Callahan Mining Company drilled an angle hole from the Haulage Tunnel. The hole was drilled to the west to a depth of 1,132 feet at a 40 degree angle from vertical.

In May, 1967 Phillips Petroleum Company optioned the property from the Squaw Peak Copper Mining Company for a term of ten years. Phillips conducted an exploration program which included 16,206.5 feet of diamond core drilling, 2756 feet of rotary drilling, 43,000 line-feet of induced polarization surveys, and 6500 feet of reflection seismic lines. Phillips terminated their option on the property in May, 1973 after a total exploration expenditure of $269,736.

In August, 1973 an option agreement was reached between the Squaw Peak Copper Mining Company and Essex, International which permitted Essex to explore the property for six months. A ten year lease-option agreement was made in February, 1974 which gave Essex sole exploration rights until 1984. The present contract is renewable in February, 1975. Essex currently owns exploration rights to 153 claims on the Squaw Peak prospect. Essex has commited approximately $53,000.00 to date on the Squaw Peak property.

## Regional Geology

The Squaw Peak area lies on the northeast perimeter of the basin and range physiographic province. The Mogollon Rim, approximately seven miles east of Squaw Peak, on the northeast flank of the Verde valley, represents the southern extremity of the Colorado Plateau province. Structural deformation and erosion have created the Verde River valley, a transition zone between the two provinces.

Rocks of Precambrian to Quaternary age outcrop in central Arizona. Precambrian rocks in Arizona are subdivided into Older and Younger Precambrian. The Older Precambrian in the Squaw Peak region is represented by a metamorphosed intermediate to mafic volcanic complex. These rocks underwent mild to intense structural deformation and low to intermediate regional metamorphism during the Mazatzal Revolution, ending the Older Precambrian (Wilson, 1936). The Mazatzal disruption culminated with a batholithic invasion of granitic to gabbroic composition. This intrusive activity probably produced a huge mountainous region, the roots of which are unconformably overlain by Paleozoic strata.

A long hiatus exists between the Paleozoic sedimentary rocks and Tertiary rocks of sedimentary and volcanic origin. Intrusive dikes and plugs of Laramide(?) age are exposed locally. Widespread late Tertiary alkali-olivene basalt covered the entire region, extending south from the Colorado Plateau. Two periods of extrusions were separated by a period of faulting and uplift of the Colorado Plateau province (McKee and

Anderson, 1971). Considerable uplift of the Black Hills during this period is demonstrated by Tertiary movement along the Verde fault zone along the northeastern front of the range. The Verde River valley was created during this period. The development of the valley was interrupted by the formation of a volcanic dam and the subsequent accumulation of lake deposits of the Verde formation (Jenkins, 1923).

The principle structural feature of the region is the Verde fault zone, which extends from Jerome, Arizona southeastward through the Squaw Peak area to approximately fifteen miles south-southeast of the Squaw Peak deposit. The Verde fault is a normal fault which parallels the northeastern base of the Black Hills and dips eastward into the Verde valley.

The Squaw Peak deposit lies within a broad structurally weak zone known as the Jerome-Wasatch orogen, a north-trending zone extending from Montana to northern Mexico. Copper metallization is known to have ascended at several locations along this zone in the Squaw Peak region, notably at Jerome, Arizona. The Precambrian United Verde massive sulfide orebody at Jerome yielded over 1.8 million tons of copper, in addition to substantial quantities of gold, silver, lead, and zinc. Other Precambrian mineralization in the Black Hills includes the Iron King massive sulfide lead-zinc mine at Humboldt, copper-bearing quartz veins at the Yaeger mine southwest of Jerome, and the Cherry Creek auriferous veins approximately twelve miles northeast of the Squaw Peak deposit. The nearest known occurrence of a major "porphyry copper" deposit is at Copper Basin, Arizona, approximately 40 airline miles west of the Squaw Peak deposit. The Bagdad prophyry copper mine is approximately 80 miles west of Squaw Peak, and the Globe-Miami porphyry copper district is 90 miles to the southeast.

## General Geology

The oldest exposed in the Squaw Peak district are a metamorphosed andesitic volcanic sequence of the Precambrian Ash Creek Goup. The Ash Creek Group was originally described from exposures in the northern Black Hills by Anderson and Creasey (1958). Zircon dating of the metavolcanics yields an age of 1820 ± 10 million years (Anderson, 1971). Due to the absence of well-defined foliation, no estimate is made here of the thickness of the Ash Creek metavolcanic rocks in the Squaw Peak area, although these rocks probably represent several thousand feet of the sequence.

In the Squaw Peak area the Ash Creek group is intruded by a large Precambrian batholith, which ranges in composition from granite to quartz diorite, with a probable average composition of granodiorite. The granodiorite-metavolcanic contact is characteristically very irregular, probably due at least in part to regional metamorphism which post-dated the granitic intrusion.

The granodiotite is intruded immediately east of the old Squaw Peak mine by a quartz monzonite porphyry stock which forms an irregular outcrop of 300 to 400 feet in diameter. Numerous dikes of quartz monzonite porphyry extend in a north-south dircetion from the parent stock. Surrounding the intrusive quartz monzonite porphyry is a zone of strong quartz-sericite alteration and associated low-grade copper and molybdenum mineralization. Less porphyritic quartz monzonite rocks which are texturally and compositionally similar to the quartz monzonite porphyry stock are exposed primarliy as northwest-trending dikes near the contact of the Precambrian granodiorite and the Ash Creek metavolcanics. The intrusion of these dikes in two particular areas along the granodiorite-metavolcanic contact has apparently resulted in the formation of two irregularly shaped breccia zones. Locally strong brecciation, quartz stockworks, and copper-bearing quartz veins and fractures are spatially related to small dikes of fine grained porphyritic quartz monzonite.

The mineralized granodiorite was dated by Phillips Petroleum using the potassium-argon method and was shown to be 1.643 billion years old. This age date is not believed to represent the time of mineralization, in which case the Squaw Peak deposit would be considered as a geologically unique occurrence, with respect to the ages of other known porphyry copper deposits in the southwestern United States. Until further age determinations are made, the ages of the quartz monzonite porphyry and of the mineralization are assumed to be Laramide, or approximately 65 million years old.

Relatively horizontal Paleozoic sedimentary rocks from 200 to 1600 feet in thickness are exposed at the western margins of the Precambrian exposures. These rocks were eroded from the central part of the Verde River valley prior to Tertiary volcanism. The base of the Paleozoic section west of the Verde fault zone is in most places about 5000 feet in elevation; however, a series of step faults in the southern portion of the mapped area have significantly lowered the base of the Paleozoic rocks. Large blocks of the Paleozoic section are also exposed immediately east of the Verde fault zone, in contact with Precambrian rocks. The exposure of Paleozoic rocks in the hangingwall of the fault range from 0 to 1500 feet in thickness. The vertical separation of the Paleozoic rocks by the Verde fault exceeds 1000 feet throughout the area and locally may exceed 3000 feet. The lowest Paleozoic unit in the Squaw Peak area is the Tapeats(?) formation of Cambrian age. The Tapeats is a coarse-grained sandstone which grades into dolomitic limestone of the Devonian Martin fromation.

Several hundred feet of basalt flows of the Tertiary Hickey formation are deposited on the erosional surface of the Martin limestone. The thickest exposure of the basalt forms the prominent pinnacle known as Squaw Peak. The Hickey basalt is exposed to a limited extent east of the Verde fault, where it overlies the Martin formation in the downthrown block of the fault zone.

A series of low-rounded hills which lie directly east of the Verde fault in the Squaw Peak mine area represent a sedimentary sequence of the Hickey formation. The Hickey sedimentary deposits in the Squaw Peak area contain primarily rounded limestone fragments up to boulder-size of the Martin formation. Lesser amounts of unconsolidated Tertiary basalt, Tapeats(?) sandstone, and Precambrian rocks are also exposed.

Weakly to moderately consolidated limestone, siltstone, and conglomeratic limestone and siltstone of the Verde formation are exposed locally in the drainages east of the Verde fault. These rocks were first described by Jenkins (1923). The Verde formation was deposited during the Pleistocene epoch as lake beds and associated fluvatile deposits throughout the upper Verde River valley.

The youngest unit in the area, other than alluvium, is a large rhyodacitic extrusive rock which outcrops in a group of prominent hills in the northeastern portion of the mapped area. The volcanic center penetrates an exposure of the Verde formation in Squaw Peak canyon. Elsewhere, rhyolitic flows up to 300 feet in thickness overlie the Verde formation. This is the only known occurrence of Quaternary volcanic rocks in the upper Verde valley region (Twenter and Metzger, 1963).

## Structural Geology

The dominant structural element in the Squaw Peak area is the Verde fault. The Verde fault zone trends north to northwest through most of the mapped area and parallels the base of the Black Hills. The Verde fault zone consists of a main fault and several subparallel and hinge faults. Most of the subordinate faults are east of the main zone, and some are obscured by recent volcanics and alluvium.

The Verde fault is a normal fault with the east side of the zone down with respect to the rocks on the west. Where exposed, the dip of the main fault zone is 40° to 70° to the east.

The Verde fault zone has been structurally weak from Precambrian to recent times. Field data from the Squaw Peak area is insufficient to define the Precambrian displacement. Precambrian vertical displacement in the Jerome area, ~~forty~~ twenty-five miles northeast of Squaw Peak, was reported to be as much as 1000 feet (Anderson and Creasey, 1958). The most conspicuous displacement in the Verde fault zone in the Squaw Peak area resulted from movement after the accumulation of the Tertiary basalts which blanket the higher ridges in the western portion of the mapped area. These basalts also outcrop at several locations on the east side of the fault zone. Total vertical displacement after deposition of the Hickey basalt ranges from 1100 to 1350 feet where the basalt is exposed on both sides of the fault. Seismic data east of the Verde fault zone in the vicinity of the Squaw Peak deposit indicate that the vertical displacement of the top of the Paleozoic section may be as much as 3000 feet. No lateral movement along the Verde fault is suggested by field evidence; however, a horizontal component may exist.

An apparent recent reversal of the Verde fault is indicated by a slightly higher elevation of the Verde formation east of the fault zone with Precambrian granodiorite on the west. Poorly consolidated gravels of the Hickey formation form a series of hills which are usually 15 to 50 feet higher than the adjacent granodiorite in the upthrown block. It is doubtful that the Verde formation has been eroded at a slower rate than the more massive granodiorite. Moreover, scattered fragments of Precambrian metavolcanic rocks are found on top of the large, prominent outcrop of recent rhodacite volcanics, indicating that substantial reverse movement may have occurred after the extrusion of the rhyodacite.

The dominant structural grain of the rocks in the area of the Squaw Peak deposit is northwest. Numerous minor fractures trend N 30°W to N 60° W through the deposit. Granitic breccia dikes, shear breccia dikes, and latite porphyry dikes surrounding the deposit trend N 25 W to ~~N W~~ North. Quartz veins in the vicinity of the deposit generally trend N 40°W to N 75° W.

The predominant northwest fabric probably represents the effects of a pre-mineralization structural grain which became enhanced during the mineralization stage. Jointing in unmineralized and unaltered granodiorite is strongest in a N40°W to N70°W direction, with dips of to to the southwest. Structural features of both mineral and post-mineral age reflect this northwest-tending, southwest-dipping fabric.

Minor drag folding on the east side of the Verde fault zone is exposed in the canyon sidewalls of Chasm Creek. The folds are apparently reverse drag folds which are related to the recent reversal of the main fault zone. A small exposure of Martin limestone exposed on the south side of the canyon has been dragged downward immediately east of the Verde fault zone. A larger fold in the Martin limestone is exposed on the north side of the canyon east of the fault zone (see Plate 1). This folding may be related to a hinge fault of the main Verde fault zone.

A series of nearly vertical step faults in the area south of the Squaw Peak deposit has displaced the base of the Tapeats(?) sandstone approximately 650 feet. These faults strike generally east-west, or at right angles to the Verde fault. The individual vertical displacements of the step faults range from 30 to 150 feet.

## Mineralization

The primary economic minerals in the Squaw Peak porphyry copper deposit are chalcopyrite and molybdenite. Chalcopyrite occurs in quartz veinlets, in fractures, in small biotite-rich pods, and as disseminated mineralization in the Precambrian granodiorite and the granodiorite-quartz monzonite porphyry contact zone. Bornite is rare. Malachite, chrysocolla, and azurite are present as secondary weathering products of chalcopyrite in a relatively shallow zone of oxidation. The oxide zone varies in thickness from 0 to 100 feet, usually not exceeding 50 feet. Molybdenite occurs with chalcopyrite, mostly in veins and fractures. The strongest molybdenite mineralization is at the margins of the quartz monzonite porphyry intrusive. Pyrite occurs with chalcopyrite and molybdenite as disseminations, in quartz veins and fractures, and in biotite blebs. Preliminary observations suggest that the chalcopyrite, molybdenite, and pyrite mineralization was concurrent. Minor amounts of gold, silver, tungsten, and rhenium are present within the zone of strongest mineralization.

Strong sulfide mineralization is exposed in a north-trending, sub-elliptical zone about 1200 feet long and 800 feet wide. The center of this zone is occupied by the quartz monzonite porphyry. The quartz monzonite porphyry stock is sulfide-deficient, except at its perimeter, where a gradational contact with the

Precambrian granodiorite is abundantly mineralized. Thus, a barren core is surrounded by a chalcopyrite-pyrite-molybdenite assemblage, which yields outward to a chalcopyrite-pyrite assemblage. Pyrite is relatively low throughout the deposit, and seldom exceeds 2 per cent by volume.

The quartz monzonite porphyry and associated mineralized zone appear to plunge 50° to 60° to the west. Copper mineralization rapidly diminishes both laterally and vertically from this zone.

Copper and molybdenum mineralization outside the strong sulfide zone is restricted principally to veins and fractures which strike predominantly northwest and dip steeply southwest. Sparse copper-bearing veins occur in a northwest-trending zone which is roughly 3500 feet long and 1500 feet wide. The quartz monzonite porphyry is at the southeastern end of this zone. Copper mineralization in the veins is usually chalcopyrite or malachite. Some native copper is present in quartz veins within the Ash Creek metamorphosed volcanics north of the deposit.

Scattered copper mineralization is also exposed in a large brecciated zone about 1500 feet northeast of the Squaw Peak deposit. The breccia zone is located at the contact between the Ash Creek metavolcanics and the granodiorite, immediately west of the Verde fault. The zone is very irregularly shaped, with a maximum dimension of about 1400 feet. Locally strong stockworks of quartz veins are associated with numerous irregular dikes of fine grained porphyritic quartz monzonite which intrude the zone. These dikes may have induced the brecciation of the granodiorite and metavolcanics. Copper mineralization consists of vein and fracture related malachite and chalcopyrite, and is almost always spatially associated with the fine grained dikes. The brecciation and mineralization are very discontinuous within the zone. The Verde Squaw prospect, which consists of a tunnel driven into the breccia zone, encountered discontinuous mineralization. A 723.6-foot-deep diamond drill hole on the southern edge of the breccia exposure was completed in 1963 by Boyles Brothers. Only weak copper mineralization was reported. A similar breccia zone is located at the granodiorite-metavolcanic contact about one mile northwest of the Squaw Peak deposit.

Sulfide mineralization is present locally within the Verde fault zone. Strong pyrite mineralization in the main shear zone is exposed in the northern portion of the mapped area. Hand samples from mineralized shears within the fault zone contain up to five per cent pyrite. No copper mineralization is indicated in the fault zone.

## Alteration

An erratic alteration zoning is developed around the quartz monzonite porphyry stock. An inner zone of strong silicification and sericitization is surrounded by a larger peripheral zone of fracture-controlled epidote-K-feldspar-calcite alteratinn. Strong quartz veining and pervasive sericite occur in an irregular, sub-elliptical area of approximately 1400 feet by 1100 feet surrounding the quartz monzonite porphyry. The quartz-sericite zone trends north-south and roughly approximates the zone of strong sulfide mineralization. The central portion of this zone is pervasively silicified, with the strongest silicification in the grada- (one word)
tional contact zone between the quartz monzonite porphyry intrusive and the Precambrian granodiorite. Sericitization is strongest towards the center of the zone. Plagioclase feldspars in the unoxidized portion of the quartz-sericite core are altered to an apple green color, which may represent partial or total replacement by sericite.

Enclosing the quartz-sericite zone is a larger area containing an epidote-orthoclase(?)-calcite assemblage, which is confined primarily to northwest-trending fractures and veins. This zone is a maximum of 4600 feet long in a north-northwest direction, and up to 2500 feet wide. Typically, the veins and fractures are zoned outward from epidote ± quartz to an envelope of salmon-colored K-feldspar. Calcite is usually present in the wallrock as thin films on microfractures. The entire assemblage seldom persists over a width of 10 centimeters. Most of the altered veins and fractures in the outer zone strike northwest and dip steeply southwest, probably reflecting the pre-mineralization structural grain. A peripheral quartz-K-feldspar-epidote-chlorite assemblage has been described in the deeper portions of other porphyry copper deposits, including Sierrita, Arizona and Bethlehem, British Columbia (Guilbert and Lowell, 1974).

The spatial and geometrical association of the mineralization and alteration with the quartz monzonite porphyry indicate that this intrusive is responsible for the Squaw Peak deposit. Strong mineralization and alteration are arranged in nearly identical zones surrounding the quartz monzonite porphyry stock. Subordinate outward mineralization and alteration appear to be controlled by a northwest-trending fracture system and by distance from the energy ~~force~~ source.

## Exploration Potential

Current information indicates a porphyry copper-molybdenum deposit of low tonnage and grade at Squaw Peak. Exploitation of the Squaw Peak deposit is subject to current and future economic circumstances. Geologic and drilling data have defined a steep-sided, bowl-shaped zone of mineralization and suggest that the mineralization terminates below this zone.

The quartz monzonite porphyry stock and associated mineralization appear to have been localized at least in part by a northwest-trending fracture system. Drilling data indicate that the quartz monzonite porphyry is an irregular columnar body, plunging 50° to 80° to the west. The structurally weak northwest-trending zone provides the most favorable location for any associated igneous activity at depth below the known Squaw Peak deposit. The existence of a deeper orebody at Squaw Peak is not supported by observations at other known porphyry copper deposits.

The potential for a faulted-off portion of the Squaw Peak deposit within the hangingwall block of the Verde fault zone is geologically intriguing. The Verde fault passes about 1800 feet northeast of the Squaw Peak deposit. The possible presence of a faulted portion of the deposit in the downthrown block of the fault is subject to : (1) the time relationship between the age of mineralization and the movement along the Verde fault; (2) the vertical extent of the Squaw Peak deposit prior to erosion; and (3) the dip of the Verde fault.

The exploration potential in the hangingwall of the Verde fault was considered by Phillips Petroleum geologists. Rotary drilling conducted by Phillips failed to penetrate the thick Tertiary basalts and sediments in the upper portion of the downthrown block. The deepest drill hole east of the fault zone was to 972 feet and bottomed in Tertiary basalt of the Hickey formation. Induced polarization, ground magnetics, and seismic surveys conducted by Phillips over the hangingwall block were inconclusive. Seismic data indicated, however, that over 2000 feet of alluvium, lake beds, and volcanic rocks overlie the top of the Paleozoic and Precambrian units east of the Verde fault zone.

The age of the copper mineralization is unknown. The youngest rock intruded by the mineralizing quartz monzonite porphyry is the Precambrian granodiorite, which yielded an age date of 1643 million years. If the mineralization is Precambrian, the target for a faulted segment of the Squaw Peak deposit would be at least 3000 feet deep. Moreover, lateral displacement along the fault may have removed the segment to an unknown distance from the Squaw Peak mine area. It is also conceivable that the currently observed fault zone is a considerable distance west from the zone which was active during the Precambrian.

The relative ages of other porphyry copper mineralization in the southwestern United States suggest that the Squaw Peak deposit was formed during the Laramide orogeny, or from late Cretaceous to mid-Tertiary time. Assuming a Laramide age for the Squaw Peak mineralization, a buried segment of the deposit east of the Verde fault may be less than 3000 feet deep, with no substantial lateral displacement. Providing that the time relationship between the Squaw Peak mineralization and the Verde fault movement is not prohibitive for the preservation of any portion of the original deposit in the fault hangingwall, the vertical extent of the initial orebody would have to be substantially greater than that which is predicted from observed small porphyry copper systems in order to reach the projected Verde fault zone.

The existence of a separate porphyry copper deposit similar to the Squaw Peak deposit is not indicated by geologic examination of the district. The presence of such a deposit may be obscured by Tertiary volcanic and sedimentary rocks and recent alluvium. The structure east of the Squaw Peak mine area is favorable for potentially economic igneous activity; however, the detection of an orebody beneath the thick Quaternary and Tertiary cover would be extremely difficult.

The two breccia zones located at the contact between the Precambrian granodiorite and the Ash Creek metamorphosed volcanic rocks are possible exploration targets. The inhomogeneous nature and the inconsistent copper mineralization suggest that no substantial ore reserves are present in these areas.

The Precambrian Ash Creek metavolcanics are of further exploration interest as a potential host for a massive sulfide deposit. The Ash Creek group served as a host for the historic United Verde orebody, located on the west side of the Verde fault, approximately 25 miles northwest of Squaw Peak. Correlation of the units in the Ash Creek group, however, is extremely difficult due to the complex history of deformation since their deposition. The most extensive surface exposure of mineralization within the metavolcanics is on the west side of the Verde fault zone, approximately 3000 feet north-northeast from the Squaw Peak deposit. The rocks here are strongly fractured, with numerous northwest-trending quartz veins containing malachite, chalcopyrite, and some native copper. The mineralization in this area is probably related to hydrothermal activity which ascended in the Verde fault zone. A 601-foot-deep drill hole, DDH 19, was drilled in this area by Phillips Petroleum, but failed to encounter significant mineralization.

## Summary and Conclusions

Precambrian granodiorite was intruded by a quartz monzonite porphyry stock, probably in Laramide time. The granodiorite subsequently hosted alteration and sulfide mineralization typical of most small porphyry copper occurrences in southwestern North America.

The Squaw Peak copper deposit contains reserves of 11,658,000 tons at a grade of 0.42% Cu, using a 0.3% Cu cut-off grade (Bellum, 1974) and a geologic inventory of 20,000,000 tons at a grade of 0.36% Cu, using a 0.2% Cu cut-off grade (Jones, 1974). Current drilling and geologic data suggest that no substantial ore reserves exist at depth below the presently defined deposit.

Other possible exploration targets in the Squaw Peak are include: (1) the east side of the Verde fault zone; (2) breccia zones; and (3) the Ash Creek group metamorphosed volcanic rocks. The potential for the discovery of additional ore reserves in these areas appears to be remote. If the Squaw Peak property is retained, future exploratory work should include deep drilling concentrating in the center of the known Squaw Peak deposit.

## References Cited

Anderson, C.A., 1951, Older Precambrian structure in Arizona; Geol. Soc. Amer. Bull., v. 62, pp. 1331-1346.

Anderson, C.A., P.M. Blacet, L.T. Silver, and T.W. Stern, 1971, Revision of Precambrian stratigraphy in the Prescott-Jerome area, Yavapai County, Arizona; U.S. Geol. Survey Bull. 1324-C, 16 p.

Anderson, C.A. and S.C. Creasey, 1958, Geology and ore deposits of the Jerome area, Yavapai County, Arizona; U.S. Geol. Survey Prof. Paper 308, 185 p.

Bellum, D.P., 1974, Squaw Peak evaluation report (unpublished), May 5, 1974, 12 p.

Guilbert, J.M. and J.D. Lowell, 1974, Variations in zoning patterns in porphyry ore deposits; Canadian Inst. of Mining Bull., Feb. 1974, pp. 99-109.

Jenkins, O.P., 1923, Verde River lake beds near Clarkdale, Arizona; Am. Jour. Sci., 5th ser., v. 5, no. 25, pp. 65-81.

Jones, J.K., 1974, Ore reserve memorandum to Essex, Int'l (unpublished).

McKee, E.H. and C.A. Anderson, 1971, Age and chemistry of Tertiary volcanic rocks in north-central Arizona and relation of the rocks to the Colorado Plateaus; Geol. Soc. Amer. Bull., v. 82, pp. 2767-2782.

Twenter, F.R. and D.G. Metzger, 1963, Geology and ground water in Verde valley--the Mogollon Rim region, Arizona; U.S. Geol. Survey Bull. 1177, 132 p.

Wilson, E.D., 1936, Precambrian Mazatzal Revolution in central Arizona; Geol. Soc. Amer. Bull., v. 50, pp. 1113-1164.

A
GEOLOGIC EVALUATION
OF THE
SQUAW PEAK PORPHYRY
COPPER DEPOSIT
YAVAPAI CO., ARIZ.
JULY, 1974

# A GEOLOGIC EVALUATION OF THE SQUAW PEAK PORPHYRY COPPER DEPOSIT YAVAPAI COUNTY, ARIZONA

Submitted by:

R. Roe

July 1974

SCANNED 5/2011 JBM

## CONTENTS

## Location and Geography

The Squaw Peak deposit is located approximately six miles south of Camp Verde, Yavapai County, Arizona. Camp Verde is approximately 35 airline miles east of Prescott, Arizona and 75 airline miles north of Phoenix. The area studied covers parts or all of Sections 24, 25, and 36, Township 13 North, Range 4 East; Sections 19, 20, 29, 30, 31, and 32, Township 13 North, Range 5 East; Section 36, Township 12½ North, Range 4 East; and Section 1, Township 12 North, Range 4 East; in addition to land of unestablished status within the Prescott National Forest. The area is contained in the Camp Verde, Horner Mountain, Arnold Mesa, and Middle Verde 7.5 minute series topographic maps.

The Squaw Peak deposit may be reached from Camp Verde by traveling south on Main Street to the Salt Mine Road, then west and south on the Salt Mine Road for approximately eight miles to the Squaw Peak Mine road. The Squaw Peak Mine road is one and one-half miles long and terminates in a network of dirt roads in the vicinity of the old Squaw Peak Mine.

The Squaw Peak area is on the eastern flanks of the Black Hills, a northwest-trending range which bounds the Verde River valley on the southwest and rises 2,000 to 3,000 feet above the valley floor in the Squaw Peak area. Squaw Peak is the highest point in the southern Black Hills and reaches an elevation of 6525 feet. The Black Hills are dissected by steep canyons and washes which drain eastward to the Verde River.

## Exploration History

Mining claims were located on the Squaw Peak prospect as early as 1883. Serious interest in the property began in 1916, when the Squaw Peak Mining Company was incorporated with the purpose of financing an exploration program at what would be known as the Squaw Peak Mine. No significant exploration was undertaken until World War II, when underground drifts and some diamond drilling were completed with the help of a $20,000 federal government loan.

Underground workings at the Squaw Peak Mine constitute about 4160 feet of drifts and about 200 feet of raises. Two levels of drifts, known as the Main Tunnel level and the Haulage Tunnel level, were driven at elevations of 4150 feet and 3850 feet, respectively. The Main Tunnel level consists of 2175 feet of drifts, and the Haulage Tunnel is 2050 feet long. Only about 500 feet of the Main Tunnel are accessible.

The first recorded ore shipments were in 1944. Production at the Squaw Peak Mine during 1944, 1945, and 1946 amounted to 5.40 tons of concentrate containing 98.82% molybdenite and 36.03 tons of concentrate containing 22.85% copper, 1.92 ounces per ton of silver, and 0.016 ounces per ton of gold. These concentrates were produced from approximately one thousand tons of ore, most of which was removed from raises on the Main Tunnel level.

Only minor exploratory drilling was undertaken from 1947 to 1967. Intermountain Exploration Company drilled two diamond drill holes totaling 601 feet from the Main Tunnel level about 450 feet from the portal during June and July, 1961. In August, 1963 Boyles Brothers Drilling Company completed a 723.6-foot vertical hole from the surface northeast of the mine. During March and April 1964 Callahan Mining Company drilled an angle hole from the Haulage Tunnel. The hole was drilled to the west to a depth of 1.132 feet at a 40 degree angle from vertical.

In May, 1967 Phillips Petroleum Company optioned the property from the Squaw Peak Copper Mining Company for a term of ten years. Phillips conducted an exploration program which included 16,206.5 feet of diamond core drilling, 2756 feet of rotary drilling, 43,000 line-feet of induced polarization surveys, and 6500 feet of reflection seismic lines. Phillips terminated their option on the property in May, 1973 after a total exploration expenditure of $269,736.

In August, 1973 an option agreement was reached between the Squaw Peak Copper Mining Company and Essex International, which permitted Essex to explore the property for six months. A ten year lease-option agreement was made in February, 1974 which gave Essex sole exploration rights until 1984. The present contract is renewable in February, 1975. Essex currently owns exploration rights of 153 claims on the Squaw Peak prospect. Essex has committed approximately $53,000 to date on the Squaw Peak property (August 1974).

## Regional Geology

The Squaw Peak area lies on the northeast perimeter of the basin and range physiographic province. The Mogollon Rim, approximately seven miles east of Squaw Peak, on the northeast flank of the Verde Valley, represents the southern extremity of the Colorado Plateau province. Structural deformation and erosion have created the Verde River Valley, a transition zone between the two provinces.

Rocks of Precambrian to Quaternary age outcrop in central Arizona. Precambrian rocks in Arizona are subdivided into Older and Younger Precambrian. The Older Precambrian in the Squaw Peak region is represented by a metamorphosed intermediate to mafic volcanic complex. These rocks underwent mild to intense structural deformation and low to intermediate regional metamorphism during the Mazatzal Revolution, ending the Older Precambrian (Wilson, 1936). The Mazatzal disruption culminated with a batholithic invasion of granitic to gabbroic composition. This intrusive activity probably produced a huge mountainous region, the roots of which are unconformably overlain by Paleozoic strata.

A long hiatus exists between the Paleozoic sedimentary rocks and Tertiary rocks of sedimentary and volcanic origin. Intrusive dikes and plugs of Laramide (?) age are exposed locally. Widespread late Tertiary alkali-olivene basalt covered the entire region, extending south from the Colorado Plateau. Two periods of extrusions were separated by a period of faulting and uplift of the Colorado Plateau province (McKee and Anderson, 1971). Considerable uplift of the Black Hills during this period is demonstrated by Tertiary movement along the Verde fault zone along the northeastern front of the range. The Verde River valley was created during this period. The development of the valley was interrupted by the formation of a volcanic dam and the subsequent accumulation of lake deposits of the Verde formation (Jenkins, 1923).

The principal structural feature of the region is the Verde fault zone, which extends from Jerome, Arizona southeastward through the Squaw Peak area to approximately fifteen miles south-southeast of the Squaw Peak deposit. The Verde fault is a normal fault which parallels the northeastern base of the Black Hills and dips eastward into the Verde Valley.

The Squaw Peak deposit lies within a broad structurally weak zone known as the Jerome-Wasatch orogen, a north-trending zone extending from Montana to northern Mexico. Copper metallization is known to have ascended at several locations along this zone in the Squaw Peak region, notably at Jerome, Arizona. The Precambrian United Verde massive sulfide orebody at Jerome yielded over 1.8 million tons of copper, in addition to substantial quantities of gold, silver, lead, and zinc. Other Precambrian mineralization in the Black Hills include the Iron King massive sulfide lead-zinc mine at Humboldt, copper-bearing quartz veins at the Yaeger Mine southwest of Jerome, and the Cherry Creek auriferous veins approximately twelve miles north-east of the Squaw Peak deposit. The nearest known occurrence of a major "porphyry copper" deposit is at Copper Basin, Arizona, approximately 40 airline miles west of the Squaw Peak deposit. The Bagdad porphyry copper mine is approximately 80 miles west of Squaw Peak, and the Globe-Miami porphyry copper district is 90 miles to the south-east.

## General Geology

The oldest exposed rocks in the Squaw Peak district are a metamorphosed andesitic volcanic sequence of the Precambrian Ash Creek Group. The Ash Creek Group was originally described from exposures in the northern Black Hills by Anderson and Creasey (1958). Zircon dating of the metavolcanics yields an age of 1820 $\pm$ 10 million years (Anderson, 1971). Due to the absence of well-defined foliation, no estimate is made here of the thickness of the Ash Creek metavolcanic rocks in the Squaw Peak area, although these rocks probably represent several thousand feet of the sequence.

In the Squaw Peak area the Ash Creek Group is intruded by a large Precambrian batholith, which ranges in composition from granite to quartz diorite, with a probable average composition of granodiorite. The granodiorite-metavolcanic contact is characteristically very irregular, probably due at least in part to regional metamorphism which post-dated the granitic intrusion.

The granodiorite is intruded immediately east of the old Squaw Peak Mine by a quartz monzonite porphyry stock which forms an irrugular outcrop of 300 to 400 feet in diameter. Numerous dikes of quartz monzonite porphyry extend in a north-south direction from the parent stock. Surrounding the intrusive quartz monzonite porphyry is a zone of strong quartz-sericite alteration and associated low-grade copper and molybdenum mineralization. Less porphyritic quartz monzonite rocks which are texturally and compositionally similar to the quartz monzonite porphyry stock are exposed primarily as northwest-trending dikes near the contact of the Precambrian granodiorite and the Ash Creek metavolcanics. The intrusion of these dikes in two particular areas along the granodiorite-metavolcanic contact has apparently resulted in the formation of two irregularly shaped breccia zones. Locally strong brecciation, quartz stockworks, and copper-bearing quartz veins and fractures are spatially related to small dikes of fine grained porphyritic quartz monzonite.

The mineralized granodiorite was dated by Phillips Petroleum using the potassium-argon method and was shown to be 1.643 billion years old. This age date is not believed to represent the time of mineralization, in which case the Squaw Peak deposit would be considered as a geologically unique occurrence, with respect to the ages of other known porphyry copper deposits in the southwestern United States. Until further age determinations are made, the ages of the quartz monzonite porphyry and of the mineralization are assumed to be Laramide, or approximately 65 million years old.

Relatively horizontal Paleozoic sedimentary rocks from 200 to 1600 feet in thickness are exposed at the western margins of the Precambrian exposures. These rocks were eroded from the central part of the Verde River valley prior to Tertiary volcanism. The base of the Paleozoic section west of the Verde fault zone is in most places about 5000 feet in elevation; however, a series of step faults in the southern portion of the mapped area have significantly lowered the base of the Paleozoic rocks. Large blocks of the Paleozoic section are also exposed immediately east of the Verde fault zone, in contact with Precambrian rocks. The exposure of Paleozoic rocks in the hangingwall of the fault range from 0 to 1500 feet in thickness. The vertical separation of the Paleozoic rocks by the Verde fault exceeds 1000 feet throughout the area and locally may exceed 3000 feet. The lowest Paleozoic unit in the Squaw Peak area is the Tapeats(?) formation of Cambrian age. The Tapeats is a coarse-grained sandstone which grades upward into dolomitic limestone of the Devonian Martin formation.

Several hundred feet of basalt flows of the Tertiary Hickey formation are deposited on the erosional surface of the Martin limestone. The thickest exposure of the basalt forms the prominent pinnacle known as Squaw Peak. The Hickey basalt is exposed to a limited extent east of the Verde fault, where it overlies the Martin formation in the downthrown block of the fault zone.

A series of low-rounded hills which lie directly east of the Verde fault in the Squaw Peak Mine area represent a sedimentary sequence of the Hickey formation. The Hickey sedimentary deposits in the Squaw Peak area contain primarily rounded limestone fragments up to boulder size of the Martin formation. Lesser amounts of unconsolidated Tertiary basalt, Tapeats(?) sandstone, and Precambrian rocks are also exposed.

Weakly to moderately consolidated limestone, siltstone, and conglomeratic limestone and siltstone of the Verde formation are exposed locally in the drainages east of the Verde fault. These rocks were first described by Jenkins (1923). The Verde formation was deposited during the Pleistocene epoch as lake beds and associated fluvatile deposits throughout the upper Verde River valley.

The youngest unit in the area, other than alluvium, is a large rhyodacitic extrusive rock which outcrops in a group of prominent hills in the northeastern portion of the mapped area. The volcanic center penetrates an exposure of the Verde formation in Squaw Peak canyon. Elsewhere, rhyolitic flows up to 300 feet in thickness overlie the Verde formation. This is the only known occurrence of Quaternary volcanic rocks in the upper Verde valley region (Twenter and Metzger, 1963).

## Structural Geology

The dominant structural element in the Squaw Peak area is the Verde fault. The Verde fault zone trends north to northwest through most of the mapped area and parallels the base of the Black Hills. The Verde fault zone consists of a main fault and several sub-parallel and hinge faults. Most of the subordinate faults are east of the main zone, and some are obscured by recent volcanics and alluvium.

The Verde fault is a normal fault with the east side of the zone down with respect to the rocks on the west. Where exposed, the dip of the main fault zone is $40^{o}$ to $70^{o}$ to the east.

The Verde fault zone has been structurally weak from Precambrian to recent times. Field data from the Squaw Peak area is insufficient to define the Precambrian displacement. Precambrian vertical displacement in the Jerome area, twenty-five miles northeast of Squaw Peak, was reported to be as much as 1000 feet (Anderson and Creasey, 1958). The most conspicuous displacement in the Verde fault zone in the Squaw Peak area resulted from movement after the accumulation of the Tertiary basalts which blanket the higher ridges in the western portion of the mapped area. These basalts also outcrop at several locations on the east side of the fault zone. Total vertical displacement after deposition of the Hickey basalt ranges from 1100 to 1350 feet where the basalt is exposed on both sides of the fault. Seismic data east of the Verde fault zone in the vicinity of the Squaw Peak deposit, however, indicate that the vertical displacement of the top of the Paleozoic section may be as much as 3000 feet. No lateral movement along the Verde fault is suggested by field evidence, although a horizontal component may exist.

An apparent recent reversal of the Verde fault is indicated by a slightly higher elevation of the Verde formation east of the fault zone with Precambrian granodiorite on the west. Poorly consolidated gravels of the Hickey formation form a series of hills which are usually 15 to 50 feet higher than the adjacent granodiorite in the upthrown block. It is doubtful that the Verde formation has been eroded at a slower rate than the more massive granodiorite. Moreover, scattered fragments of Precambrian metavolcanic rocks are found on top of the large, prominent outcrop of recent rhyodacite volcanics, indicating that substantial reverse movement may have occurred after the extrusion of the rhyodactite.

The dominant structural grain of the rocks in the area of the Squaw Peak deposit is northwest. Numerous minor fractures trend N30°W to N60°W through the deposit. Granitic breccia dikes, shear breccia dikes, and latite porphyry dikes surrounding the deposit trend N25°W to North. Quartz veins in the vicinity of the deposit generally trend N40°W to N75°W.

The predominant northwest fabric probably represents the effects of a pre-mineralization structural grain which became enhanced during the mineralization stage. Jointing in unmineralized and unaltered granodiorite is strongest in a N40°W to N70°W direction, with dips of 60° to 80° to the southwest. Structural features of both pre-mineral and post-mineral age reflect this northwest-trending, southwest-dipping fabric.

Minor drag folding on the east side of the Verde fault zone is exposed in the canyon sidewalls of Chasm Creek. The folds are apparently reverse drag folds which are related to the recent reversal of the main fault zone. A small exposure of Martin limestone exposed on the south side of the canyon has been dragged downward immediately east of the Verde fault zone. A larger fold in the Martin limestone is exposed on the north side of the canyon east of the fault zone (see Plate 1). This folding may be related to a hinge fault of the main Verde fault zone.

A series of nearly vertical step faults in the area south of the Squaw Peak deposit has displaced the base of the Tapeats(?) sandstone approximately 650 feet. These faults strike generally east-west, or at right angles to the Verde fault. The individual vertical displacements of the step faults range from 30 to 150 feet.

## Mineralization

The primary economic minerals in the Squaw Peak porphyry copper deposit are chalcopyrite and molybdenite. Chalcopyrite occurs in quartz veinlets, in fractures, in small biotite-rich pods, and as disseminated mineralization in the Precambrian granodiorite and the granodiorite-quartz monzonite porphyry contact zone. Bornite is rare. Malachite, chrysocolla, and azurite are present as secondary weathering products of chalcopyrite in a relatively shallow zone of oxidation. The oxide zone varies in thickness from 0 to 100 feet, usually not exceeding 50 feet. Molybdenite occurs with chalcopyrite, mostly in veins and fractures. The strongest molybdenite mineralization is at the margin of the quartz monzonite porphyry intrusive. Pyrite occurs with chalcopyrite and molybdenite as disseminations, in quartz veins and fractures, and in biotite blebs. Preliminary observations suggest that the chalcopyrite, molybdenite, and pyrite mineralization was concurrent. Minor amounts of gold, silver, tungsten, and rhenium are present within the zone of strongest mineralization.

Strong sulfide mineralization is exposed in a north-trending sub-elliptical zone about 1200 feet long and 800 feet wide. The center of this zone is occupied by the quartz monzonite porphyry. The quartz monzonite porphyry stock is sulfide-deficient, except at its perimeter, where a gradational contact with the Precambrian granodiorite is abundantly mineralized. Thus, a barren core is surrounded by a chalcopyrite-pyrite-molybdenite assemblage, which yields outward to a chalcopyrite-pyrite assemblage. Pyrite is relatively low throughout the deposit, and seldom exceeds 2 per cent by volume.

The quartz monzonite porphyry and associated mineralized zone appear to plunge $50^{o}$ to $60^{o}$ to the west. Copper mineralization rapidly diminishes both laterally and vertically from this zone.

Copper and molybdenum mineralization outside the strong sulfide zone is restricted principally to veins and fractures which strike predominantly northwest and dip steeply southwest. Sparse copper-bearing veins occur in a northwest-trending zone which is roughly 3500 feet long and 1500 feet wide. The quartz monzonite porphyry is at the southeastern end of this zone. Copper mineralization in the veins is usually chalcopyrite or malachite. Some native copper is present in quartz veins within the Ash Creek metamorphosed volcanics north of the deposit.

Scattered copper mineralization is also exposed in a large brecciated zone about 1500 feet northeast of the Squaw Peak deposit.

The breccia zone is located at the contact between the Ash Creek metavolcanics and the granodiorite, immediately west of the Verde fault. The zone is very irregularly shaped, with a maximum dimension of about 1400 feet. Locally strong stockworks of quartz veins are associated with numerous irregular dikes of fine grained porphyritic quartz monzonite which intrude the zone. These dikes may have induced the brecciation of the granodiorite and metavolcanics. Copper mineralization consists of vein and fracture related malachite and chalcopyrite, and is almost always spatially associated with the fine grained dikes. The brecciation and mineralization are very discontinuous within the zone. The Verde Squaw prospect, which consists of a tunnel driven into the breccia zone, encountered discontinuous mineralization. A 723.6-foot-deep diamond drill hole on the southern edge of the breccia exposure was completed in 1963 by Boyles Brothers. Only weak copper mineralization was reported. A similar breccia zone is located at the granodiorite-metavolcanic contact about one mile northwest of the Squaw Peak deposit.

Sulfide mineralization is present locally within the Verde fault zone. Strong pyrite mineralization in the main shear zone is exposed in the northern portion of the mapped area. Hand samples from mineralized shears within the fault zone contain up to five per cent pyrite. No copper mineralization is indicated in the fault zone.

## Alteration

An erratic alteration zoning is developed around the quartz monzonite porphyry stock. An inner zone of strong silicification and sericitization is surrounded by a larger peripheral zone of fracture-controlled epidote-K-feldspar-calcite alteration. Strong quartz veining and pervasive sericite occur in an irregular, sub-elliptical area of approximately 1400 feet by 1100 feet surrounding the quartz monzonite porphyry. The quartz-sericite zone trends north-south and roughly approximates the zone of strong sulfide mineralization. The central portion of this zone is pervasively silicified, with the strongest silicification in the gradational contact zone between the quartz monzonite porphyry intrusive and the Precambrian granodiorite. Sericitization is strongest towards the center of the zone. Plagioclase feldspars in the unoxidized portion of the quartz-sericite core are altered to an apple green color, which may represent partial or total replacement by sericite.

Enclosing the quartz-sericite zone is a larger area containing an epidote-orthoclase(?)-calcite assemblage, which is confined primarily to northwest-trending fractures and veins. This zone is a maximum of 4600 feet long in a north-northwest direction, and up to 2500 feet wide. Typically, the veins and fractures are zoned outward from epidote ± quartz to an envelope of salmon-colored K-feldspar. Calcite is usually present in the wallrock as thin films on microfractures. The entire assemblage seldom persists over a width of 10 centimeters. Most of the altered veins and fractures in the outer zone strike northwest and dip steeply southwest, probably reflecting the pre-mineralization structural grain. A peripheral quartz-K-feldspar-epidote-chlorite assemblage has been described in the deeper portions of other porphyry copper deposits, including Sierrita, Arizona and Bethlehem, British Columbia (Guilbert and Lowell, 1974).

The spatial and geometrical association of the mineralization and alteration with the quartz monzonite porphyry indicate that this intrusive is responsible for the Squaw Peak deposit. Strong mineralization and alteration are arranged in nearly identical zones surrounding the quartz monzonite porphyry stock. Subordinate outward mineralization and alteration appear to be controlled by a northwest-trending fracture system and by distance from the energy source.

## Exploration Potential

Current information indicates a porphyry copper-molybdenum deposit of low tonnage and grade at Squaw Peak. Exploitation of the Squaw Peak deposit is subject to current and future economic circumstances. Geologic and drilling data have defined a steep-sided, bowl-shaped zone of mineralization and suggest that the mineralization terminates below this zone. A set of maps and ore reserve calculations completed by Essex geologist J. Kenneth Jones are available in the Tucson office.

The quartz monzonite porphyry stock and associated mineralization appear to have been localized at least in part by a northwest-trending fracture system. Drilling data indicates that the quartz monzonite porphyry is an irregular columnar body, plunging 50° to 80° to the west. The structurally weak northwest-trending zone provides the most favorable location for any associated igneous activity at depth below the known Squaw Peak deposit. The existence of a deeper orebody at Squaw Peak is not supported by observations at other known porphyry copper deposits.

The potential for a faulted-off portion of the Squaw Peak deposit within the hangingwall block of the Verde fault zone is geologically intriguing. The Verde fault passes about 1800 feet northeast of the Squaw Peak deposit. The possible presence of a faulted portion of the deposit in the downthrown block of the fault is subject to: (1) the time relationship between the age of mineralization and the movement along the Verde fault; (2) the vertical extent of the Squaw Peak deposit prior to erosion; and (3) the dip of the Verde fault.

The exploration potential in the hangingwall of the Verde fault was considered by Phillips Petroleum geologists. Rotary drilling, conducted by Phillips failed to penetrate the thick Tertiary basalts and sediments in the upper portion of the downthrown block. The deepest drill hole east of the fault zone was to 972 feet and bottomed in Tertiary basalt of the Hickey formation. Induced polarization, ground magnetics, and seismic surveys conducted by Phillips over the hangingwall block were inconclusive. Seismic data indicated, however, that over 2000 feet of alluvium, lake beds, and volcanic rocks overlie the top of the Paleozoic and Precambrian units east of the Verde fault zone.

The age of the copper mineralization is unknown. The youngest rock intruded by the mineralizing quartz monzonite porphyry is the Precambrian granodiorite, which yielded an age date of 1643 million years.

If the mineralization is Precambrian, the target for a faulted segment of the Squaw Peak deposit would be at least 3000 feet deep. Moreover, lateral displacement along the fault may have removed the segment to an unknown distance from the Squaw Peak mine area. It is also conceivable that the currently observed fault zone is a considerable distance west from the zone which was active during the Precambrian.

The relative ages of other porphyry copper mineralization in the southwestern United States suggest that the Squaw Peak deposit was formed during the Laramide orogeny, or from late Cretaceous to mid-Tertiary time. Assuming a Laramide age for the Squaw Peak mineralization, a buried segment of the deposit east of the Verde fault may be less than 3000 feet deep, with no substantial lateral displacement. Providing that the time relationship between the Squaw Peak mineralization and the Verde fault movement is not prohibitive for the preservation of any portion of the original deposit in the fault hangingwall, the vertical extent of the initial orebody would have to be substantially greater than that which is predicted from observed small porphyry copper systems in order to reach the projected Verde fault zone.

The existence of a separate porphyry copper deposit similar to the Squaw Peak deposit is not indicated by geologic examination of the district. The presence of such a deposit may be obscured by Tertiary volcanic and sedimentary rocks and recent alluvium. The structure east of the Squaw Peak mine area is favorable for potentially economic igneous activity; however, the detection of an orebody beneath the thick Quaternary and Tertiary cover would be extremely difficult.

The two breccia zones located at the contact between the Precambrian granodiorite and the Ash Creek metamorphosed volcanic rocks are possible exploration targets. The inhomogeneous nature and the inconsistent copper mineralization suggest that no substantial ore reserves are present in these areas.

The Precambrian Ash Creek metavolcanics are of further exploration interest as a potential host for a massive sulfide deposit. The Ash Creek group served as a host for the historic United Verde orebody, located on the west side of the Verde fault, approximately 25 miles northwest of Squaw Peak. Correlation of the units in the Ash Creek group, however, is extremely difficult due to the complex history of deformation since their deposition. The most extensive surface exposure of mineralization within the metavolcanics is on the west side of the Verde fault zone, approximately 3000 feet north-northeast from the Squaw Peak deposit. The rocks here are strongly fractured, with numerous northwest-trending quartz veins containing malachite, chalcopyrite, and some native copper. The mineralization in this area is probably related to hydrothermal activity which ascended in the Verde fault zone. A 601-foot-deep drill hole, DDH 19, was drilled in this area by Phillips Petroleum, but failed to encounter significant mineralization.

## Summary and Conclusions

Precambrian granodiorite was intruded by a quartz monzonite porphyry stock, probably in Laramide time. The granodiorite subsequently hosted alteration and sulfide mineralization typical of most small porphyry copper occurrences in southwestern North America.

The Squaw Peak copper deposit contains reserves of 11,658,000 tons at a grade of 0.42% Cu, using a 0.3% Cu cut-off grade (Bellum, 1974) and a geologic inventory of 20,000,000 tons at a grade of 0.36% Cu, using a 0.2% Cu cut-off grade (Jones, 1974). Current drilling and geologic data suggest that no substantial ore reserves exist at depth below the presently defined deposit.

Other possible exploration targets in the Squaw Peak area include: (1) the east side of the Verde fault zone; (2) breccia zones; and (3) the Ash Creek group metamorphosed volcanic rocks. The potential for the discovery of additional ore reserves in these areas appears to be remote. If the Squaw Peak property is retained, future exploratory work should include deep drilling concentrating in the center of the known Squaw Peak deposit.

## References Cited


Anderson, C.A., 1951, Older Precambrian structure in Arizona; Geol. Soc. Amer. Bull., v. 62, pp. 1331-1346.

Anderson, C.A., P.M. Blacet, L.T. Silver, and T.W. Stern, 1971, Revision of Precambrian stratigraphy in the Prescott-Jerome area, Yavapai County, Arizona; U.S. Geol. Survey Bull. 1324-C, 16 p.

Anderson, C.A. and S.C. Creasey, 1958, Geology and ore deposits of the Jerome area, Yavapai County, Arizona; U.S. Geol. Survey Prof. Paper 308, 185 p.

Bellum, D.P., 1974, Squaw Peak evaluation report (unpublished) May 5, 1974, 12 p.

Guilbert, J.M. and J.D. Lowell, 1974, Variations in zoning patterns in porphyry ore deposits; Canadian Inst. of Mining Bull., Feb. 1974, pp. 99-109.

Jenkins, O.P., 1923, Verde River lake beds near Clarkdale, Arizona; Am. Journal Sci., 5th ser., v. 5, no. 25, pp. 65-81.

Jones, J.K., 1974, Ore reserve memorandum to Essex International (unpublished).

McKee, E.H. and C.A. Anderson, 1971, Age and chemistry of Tertiary volcanic rocks in north-central Arizona and relation of the rocks to the Colorado Plateaus; Geol. Soc. Amer. Bull., v. 82, pp. 1767-2782.

Twenter, F.R. and D.G. Metzger, 1963, Geology and ground water in Verde valley--the Mogollon Rim region, Arizona; U.S. Geol. Survey Bull. 1177, 132 p.

Wilson, E.D., 1936, Precambrian Mazatzal Revolution in central Arizona; Geol. Soc. Amer. Bull., v. 50, pp. 1113-1164.

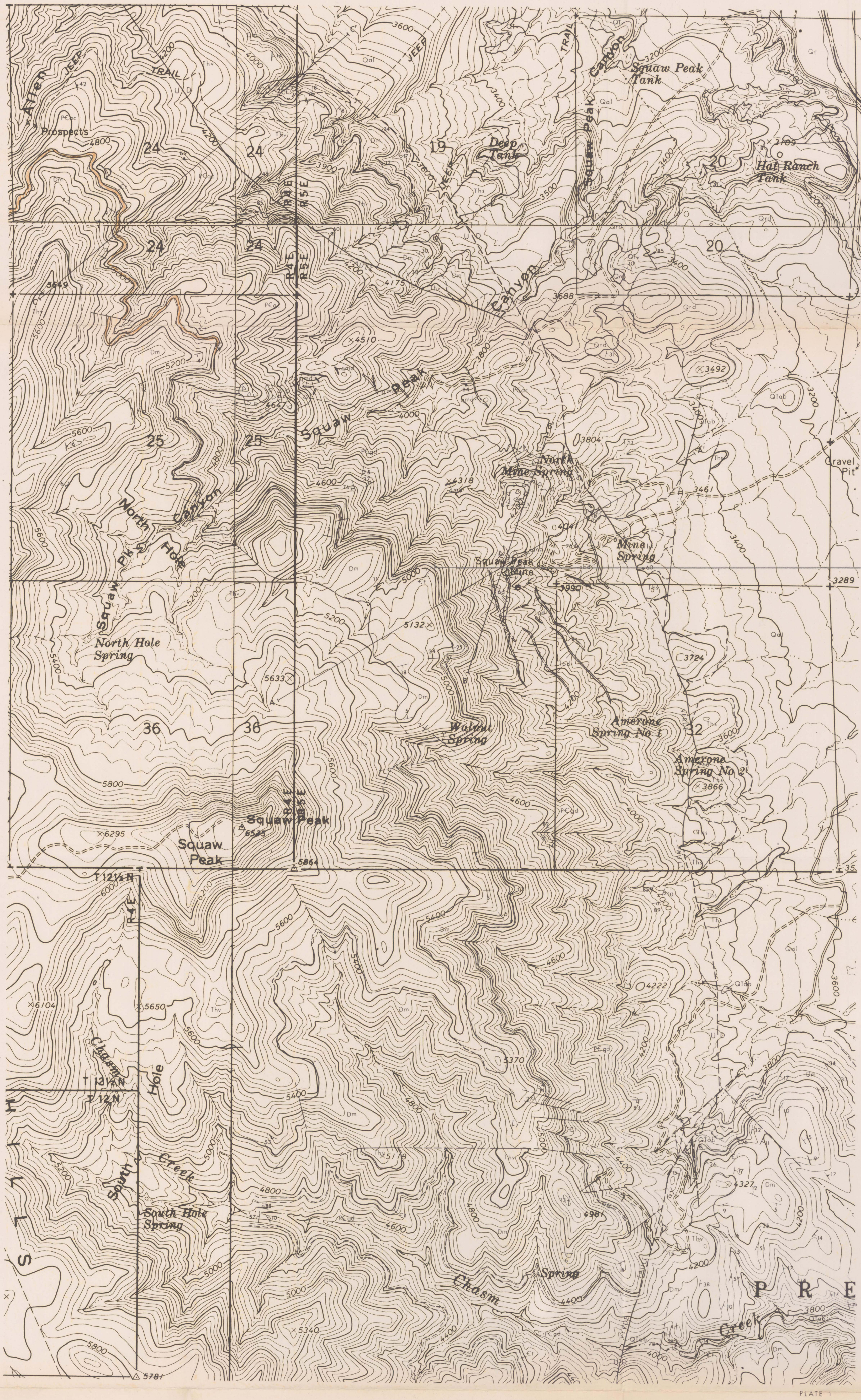



PLATE 1

# EXPLANATION

| Age | Symbol | Description |
|---|---|---|
| Recent | Qr | Riverwash |
| Recent | Qal | Alluvium |
| | | unconformity |
| Pleistocene | Qrd | Rhyodacite flows |
| | | unconformity |
| Pleistocene | QTv | Verde formation |
| | | unconformity |
| Pliocene(?) | QTab | Andesite and basalt volcanic rocks |
| | | unconformity |
| Pliocene(?) | Ths | Hickey formation; gravels |
| Pliocene(?) | Thv | Hickey formation; volcanic rocks |
| | | unconformity |
| Laramide(?) | bz | Breccia zones |
| Laramide(?) | sb, sbd | Shear breccia, sb; shear breccia dikes, sbd |
| Laramide(?) | lpd | Latite porphyry dikes |
| Laramide(?) | bd | Granitic breccia dikes |
| Laramide(?) | qmp, qmd | Quartz monzonite porphyry, qmp; quartz monzonite dikes, qmd |
| | | unconformity |
| Middle(?) and Upper Devonian (DEVO-) | Dm | Martin limestone |
| | | unconformity(?) |
| CAM- | €t | Tapeats(?) sandstone |
| | | unconformity |
| PRECAMBRIAN | P€gd | Granodiorite |
| | | unconformity |
| PRECAMBRIAN | P€ac | Ash Creek group metamorphosed basalt and andesite flows and breccia; also porphyritic andesitic flows and agglomerate |

Contact
dashed where approximately located; dotted where concealed

U / D

Fault, showing dip
dashed where approximately located; dotted where concealed; U, upthrown side; D, downthrown side

58 / 15

Minor fold
showing strike and dip of axial plane and trend and plunge of axis

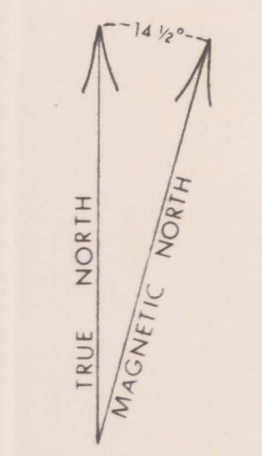
34 — Strike and dip of beds

55 — Strike and dip of foliation

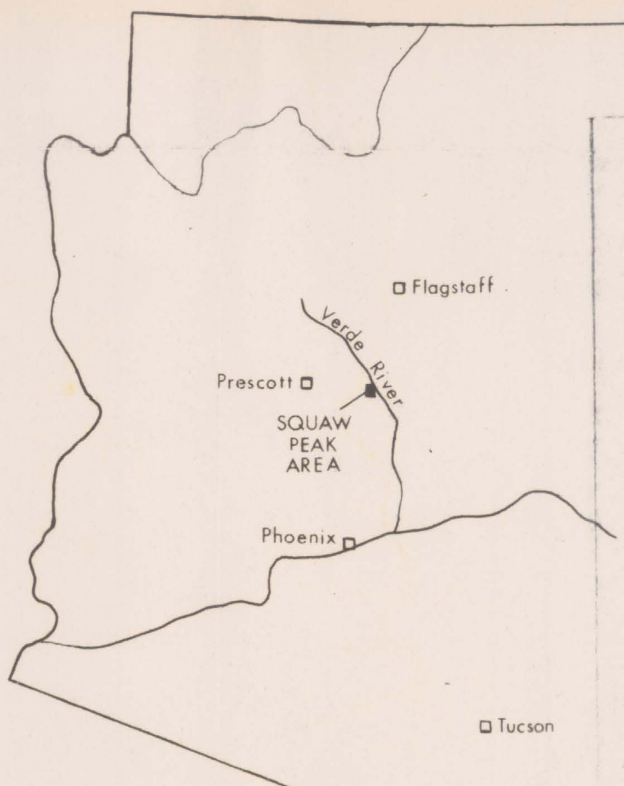
16 — Strike and dip of planar flow structure

76 — Strike and dip of joints

Strike and dip of vertical joints




APPROXIMATE MEAN DECLINATION 1969




# GEOLOGIC MAP OF THE SQUAW PEAK AREA

## YAVAPAI COUNTY, ARIZONA

SCALE 1:12000

ONE INCH EQUALS ONE THOUSAND FEET

2000 1000 0 1000 2000 3000 4000 5000

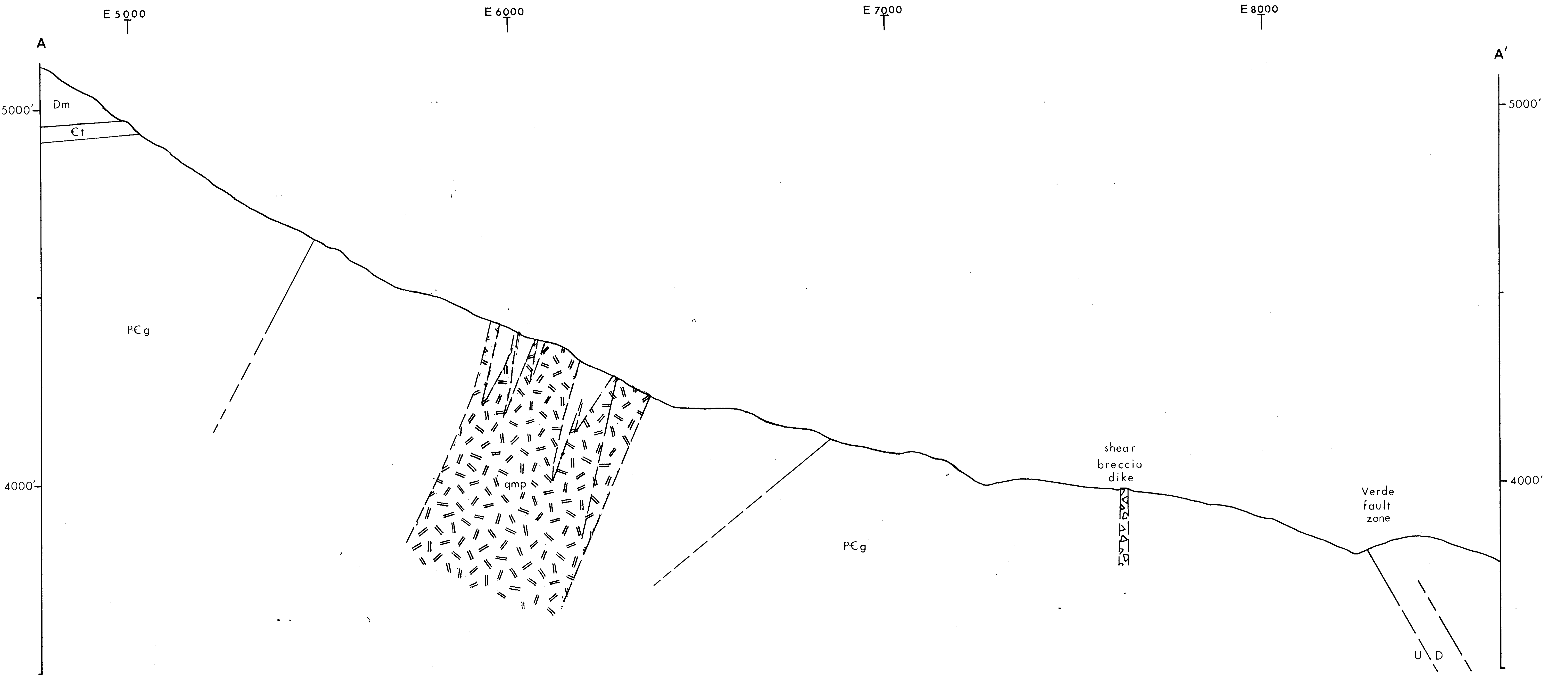
Contour Interval 40 Feet


**ESSEX** | ESSEX INTERNATIONAL, INC.
1704 WEST GRANT RD., TUCSON, ARIZONA 85705
PHONE (602) 624-7421


PROJECT: SQUAW PEAK
PROSPECT:
NUMBER:
COUNTY, STATE: YAVAPAI, ARIZ.
LAT., LONG.:
T., R., & SECTION: T12, 12½N; R4, 5E

GEOLOGIC MAP OF AREA

SCALE: 1" = 1000'
DATE: JULY, 1974
DATA BY: R. ROE
PREPARED BY: R. ROE




# GEOLOGIC SECTION A - A′

**LOOKING NORTH**

ONE INCH EQUALS 200 FEET

ESSEX | ESSEX INTERNATIONAL, INC. 1704 WEST GRANT RD., TUCSON, ARIZONA 85705 PHONE (602) 624-7421

| | |
|---|---|
| PROJECT: | SQUAW PEAK |
| PROSPECT: | |
| NUMBER: | |
| COUNTY, STATE: | YAVAPAI, ARIZ |
| T., R. & SECTION: | T12½N, R5E |
| LATITUDE, LONGITUDE: | |

GEOLOGIC SECTION

| | |
|---|---|
| SCALE: | 1" = 200' |
| DATE: | JULY, 1974 |
| DATA BY: | R. ROE |
| PREPARED BY: | R. ROE |

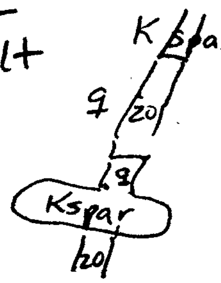
# A GEOLOGIC EVALUATION OF THE SQUAW PEAK PORPHYRY COPPER DEPOSIT YAVAPAI COUNTY, ARIZONA

# PHOTOMICROGRAPHS

| No. | Sample | Description | (2.8-f-stop) shutter |
|---|---|---|---|
| • A 1 | 1-447 | 2ndary Kspar, bt; sulfides | 8 |
| 2 | | plane light 3.5x | 15 |
| • 3 | 1-618 | shreddy, green (2ndary?) bt | 4 |
| 4 | | w/ Kspar | 8 |
| 5 | | pl. lt. 10x | 15 |
| • 6 | 1-993 | epid + chlor alt'n w/ py? xl | 2 |
| 7 | | seric. | 4 |
| 8 | | X-nichols 3.5x | 8 |
| 9 | 7-186 | seric. surr. q grain w/ sulf. | 2 |
| 10 | | min'l; bt part. repl. by seric. | 4 |
| • 11 | | X-n. 10x | 1 |
| • 12 | 9-441 | zois + q repl. bt xl | 1 |
| 13 | | chlor repl. bt; ser. alt. of plag; ser-sulf. unit. | 2 |
| 14 | | X-n. 3.5x | 4 |
| • 15 | 14-955 | Amph. xl repl. by chlor-carb- | 1 |
| 16 | | ep-q mont | 2 |
| 17 | | X-n. 3.5x | 4 |
| • 18 | 18-102 | epid-Kspar alt (flooding) | 2 |
| 19 | | | 4 |
| 20 | | X-n. 3.5x | 8 |
| • 21 | 9-5-A | seric + clay alt'd plag phenos | 8 |
| 22 | | v. fine gr. matrix of q + Kspar (stn.) | 15 |
| 23 | | X-nichols 3.5x | 30 |
| • 24 | SPI | subhed. plag pheno. (rel. fresh) | 1 |
| 25 | | in microgran. text. of | 2 |
| 26 | | q, bt, Kspar, chlor | 4 |
| | | x-nich. 10x | |

| | | | | |
|---|---|---|---|---|
| ● | 27 | 12-5-B | subhed. Kspar, q, plag | 15 |
| | 28 | | (stain) | 30 |
| | 29 | | X-nichols 3.5x | 60 |
| ● | 30 | HB | twinned olivene xl; plag | 2 |
| | 31 | | laths, magnetite | 4 |
| | 32 | | X-nich 3.5x | 8 |
| | 33 | 19-204 | carb. vn offsets carb-q vn | 1 |
| | 34 | | in Ptac - sub-// chlor grns | 2 |
| | 35 | | in microbase of seric(?) x-nich 3.5x | 4 |
| | 36 | 3-570 | bt → chlor ± zois | 1 |
| | 37 | | x-nich 3.5x | 2 |
| | 38 | | (end of roll) | B |
| B | 1 | SPI | | 1 |
| | 2 | | alb. rim on plag | 2 |
| | 3 | | x-nich 10x | 4 |
| ● | 4 | | | 1 |
| ● | 5 | 1-452 | ser repl. bt | 1 |
| | 6 | | " alt felds | 2 |
| | 7 | | | 4 |
| ● | 8 | 1-591 | sulf. in fresh bt mass | 1 |
| | 9 | | in q + Kspar groundmass X-n. 3.5x | 2 |
| | 10 | 1-993 | ~~alb of plag xl~~ 2nd. bt w/ ~~sulf~~ ? over-exposed | 60 |
| | 11 | | | 125 |
| | 12 | | | 250 |
| | 13 | | alb. of plg xls | 8 |
| | 14 | | ~~obscure~~ | 15 |
| | 15 | | underexposed | 30 |

| | | | | |
|---|---|---|---|---|
| | 16 | 6-25+ | sheared frac w/ chlor-zois- | 30 |
| | 17 | | suff. alt'n. | 30 |
| • | 18 | | x-nich. 3.5x | 1 |
| | 19 | | | 2 |
| • | 20 | 19-20+ | P€ac | 1 |
| | 21 | | X-nich 10x | 2 |
| | 22 | | | 4 |
| • | 23 | AP-2a | zois on lt | 1 |
| | 24 | | X-nich 3.5x | 2 |
| • | 25 | 16-510 | $MoS_2$ rosette | 1 |
| | 26 | | x-nich 10x | 2 |
| • | 27 | 10-460 | cpy | 1 |
| | 28 | | x-n. 10x | 2 |
| • | 29 | 16-936 | sheared spec w/ int. ser | 1 |
| | 30 | | X-n 10x | 2 |
| • | 31 | 7-486 | bimodal bt surr by | 1 |
| | 32 | | plag (wkly alt) + q | 2 |
| | 33 | | pl. lt. 3.5x | 4 |
| • | 34 | 1-447 | 2nd. bt + Kspar | 2 |
| | 35 | | pl. lt. 3.5x | 4 |
| | 36 | | | 8 |
| • | 37 | 7-280 | apatite recryst 10x pl. lt. | 1 |



TELEPHONE
(416) 363-2636

330 Bay Street, Suite 908
Toronto, Canada
M5H 2S8

CABLES
SURVEYMIN
TORONTO

August 29, 1975

Mr. E. Grover Heinrichs
Exploration Manager
Essex International, Inc.
Metallurgical & Mining Division
1704 West Grant Road
Tucson, Arizona 85705

Re: Sqaw Peak Property

Dear Mr. Heinrichs:

Please pardon the delay in answering your letter concerning the above property. I very much appreciate you sending me the information on it.

It seems unlikely that we would be interested in this property at the present time.

If I have the opportunity to be in Arizona I will certainly give you a call. Should your company have anything of interest in Canada I would be pleased to be of service to you.

Yours very truly,

J. A. Harquail
Consulting Engineer

JAH:SW

plot poles to planes on stereonet

MIN'LIZED FRACS & UNS.

| | |
|---|---|
| N 78 W | 80 |
| N 56 W | 60 |
| N 89 W | 85 N |
| N 30 W | V |
| N 43 W | 60 |
| N 45 W | 75 |
| N 54 W | 80 |
| N 84 W | V |
| N 24 W | 76 |
| N 33 W | 70 |
| N 31 W | 80 |
| N 3 E | 30 W |
| ~~N 45 W~~ | ~~V~~ |
| ~~N 30 W~~ | ~~78~~ |
| ~~N 37 W~~ | ~~71~~ |
| ~~N 28 W~~ | ~~48~~ |
| ~~N 30 W~~ | ~~80~~ |
| ~~N 14 W~~ | ~~80~~ |
| ~~N 45 W~~ | ~~75~~ |
| ~~N 26 E~~ | ~~65 NW~~ |
| ~~N 30 W~~ | ~~42~~ |
| ~~N 58 W~~ | ~~59~~ |
| ~~N 26 W~~ | ~~75~~ |
| ~~N 28 W~~ | ~~70~~ |
| ~~N 24 W~~ | ~~70~~ |
| ~~N 3 W~~ | ~~78~~ |
| N 25 W | 65 |
| N 60 W | 71 |

| | |
|---|---|
| N48W | 80 |
| N2W | 85 |
| N10W | 70 |

# BLOCK # 4

| Fm. | Lithology | Thickness |
| --- | --- | --- |
| | brown ss | 15' + |
| Dakota | carb silt | 15' |
| | grey shale | 25' |
| | • brown ss | 30-120' |
| | | 85-175' |
| | green to grey silt & ss | 25-35' |
| Burro Canyon | • tan ss | 20-50' |
| | green silt | 0-30' |
| | | 45-115' |
| | red sh + silt | 10-40' |
| Morrison | green + red siltstone | 85-105' |
| (Brushy Basin Mbr.) | • tan ss (#15) | 20-110' |
| | | 115-255' |
| (Salt Wash Mbr?) | red & green ss to shale<br>local ls | |

# BLOCK #2

| Fm. | Lith. | Thickness |
| --- | --- | --- |
| | grey-tan ss & siltst. | 5-50' |
| Dakota | • grey shale & carbonaceous sh | 15' |
| | • tan to grey siltst to ss | 20-30' |
| | grey siltstone | 20-25' |
| | | 60-120' |
| Burro | • tan ss | 45-50' |
| Canyon | • green-grey siltst | 15-30' |
| | • tan ss, congl. at base | 50' |
| | | 60-130' |
| Morrison | red-grn sh & siltst, | |
| (Brushy Basin Mbr) | local tan siltst. | |

# BLOCK #3

| Fm. | Lith. | Thickness |
|---|---|---|
| Burro Canyon | green-grey sh & siltst. | 20' + |
| | • tan ss | 45' |
| | | 65' + |
| | red & green siltst | 10-85' |
| Morrison | tan to greenish tan ss | 20-90' |
| (Brushy Basin Mbr) | red siltst | 20-80' |
| | • tan (#15) to grey ss & siltst | 75-140' |
| | grey ss cngl | 10-20' |
| | | [illegible]' |
| | | 195-325' |
| (Salt Wash Mbr?) | red siltst | |

# STRATIGRAPHY : BLOCK #1

| Formation | Lithology | Thickness |
|---|---|---|
| Mancos | grey silty shale | 25' |
| Dakota | grey to tan ss & siltstone, local black shale | 25-60' |
| | • carbonaceous shale to carb. ss | 13-20' |
| | • grey siltstone to ss | 0-40' |
| | | 38-120' |
| Burro Canyon | • grey ss, local grey-grn sh | 0-57' |
| Morrison (Brushy Basin Mmbr.) | red & green sh & siltstone | |

PDH # 18

Selected Intervals

| Interval | Cu/Mo | $MoS_2$ | % Mo | Cu |
|---|---|---|---|---|
| 10 - 45 | 50 | .004 | .002 | 0.10 |
| 45 - 60 | 55 | .007 | .004 | 0.22 |
| 60 - 150 | 60 | .003 | .002 | 0.12 |
| 150 - 165 | 280 | .002 | .001 | 0.28 |
| 165 - 285 | 30 | .006 | .004 | 0.12 |
| 285 - 300 | 54 | .008 | .005 | 0.27 |
| 300 - 435 | 14 | .016 | .009 | 0.13 |
| 435 - 719 | 22 | .018 | .011 | 0.24 |

ESSEX

ESSEX INTERNATIONAL, INC.
METALLURGICAL & MINING DIVISION
1704 WEST GRANT RD., TUCSON, ARIZONA 85705 • PHONE (602) 624-7421

DPH 1

| | Cu | Mo | Cu/Mo |
|---|---|---|---|
| 5-75 | .65 | .017 | 38 |
| 75-175 | .50 | .014 | 36 |
| 175-250 | .31 | .023 | 13 |
| 250-325 | .24 | .019 | 13 |
| 325-475 | .18 | .006 | 30 |
| 475-565 | .24 | .016 | 15 |
| 565-800 | .12 | .004 | 30 |
| 800-830 | .23 | .011 | 21 |
| 830-900 | .13 | .008 | 16 |
| 900-1000 | .07 | .003 | 23 |

# A

# GEOLOGIC EVALUATION

# OF THE

# SQUAW PEAK PORPHYRY

# COPPER DEPOSIT

# YAVAPAI COUNTY, ARIZONA

Submitted by:

R. Roe

July 1974

# CONTENTS

## Location and Geography

The Squaw Peak deposit is located approximately six miles south of Camp Verde, Yavapai County, Arizona. Camp Verde is approximately 35 airline miles east of Prescott, Arizona and 75 airline miles north of Phoenix. The area studied covers parts or all of Sections 24, 25, and 36, Township 13 North, Range 4 East; Sections 19, 20, 29, 30, 31, and 32, Township 13 North, Range 5 East; Section 36, Township 12½ North, Range 4 East; and Section 1, Township 12 North, Range 4 East; in addition to land of unestablished status within the Prescott National Forest. The area is contained in the Camp Verde, Horner Mountain, Arnold Mesa, and Middle Verde 7.5 minute series topographic maps.

The Squaw Peak deposit may be reached from Camp Verde by traveling south on Main Street to the Salt Mine Road, then west and south on the Salt Mine Road for approximately eight miles to the Squaw Peak Mine road. The Squaw Peak Mine road is one and one-half miles long and terminates in a network of dirt roads in the vicinity of the old Squaw Peak Mine.

The Squaw Peak area is on the eastern flanks of the Black Hills, a northwest-trending range which bounds the Verde River valley on the southwest and rises 2,000 to 3,000 feet above the valley floor in the Squaw Peak area. Squaw Peak is the highest point in the southern Black Hills and reaches an elevation of 6525 feet. The Black Hills are dissected by steep canyons and washes which drain eastward to the Verde River.

## Exploration History

Mining claims were located on the Squaw Peak prospect as early as 1883. Serious interest in the property began in 1916, when the Squaw Peak Mining Company was incorporated with the purpose of financing an exploration program at what would be known as the Squaw Peak Mine. No significant exploration was undertaken until World War II, when underground drifts and some diamond drilling were completed with the help of a $20,000 federal government loan.

Underground workings at the Squaw Peak Mine constitute about 4160 feet of drifts and about 200 feet of raises. Two levels of drifts, known as the Main Tunnel level and the Haulage Tunnel level, were driven at elevations of 4150 feet and 3850 feet, respectively. The Main Tunnel level consists of 2175 feet of drifts, and the Haulage Tunnel is 2050 feet long. Only about 500 feet of the Main Tunnel are now accessible.

The first recorded ore shipments were in 1944. Production at the Squaw Peak Mine during 1944, 1945, and 1946 amounted to 5.40 tons of concentrate containing 98.82% molybdenite and 36.03 tons of concentrate containing 22.85% copper, 1.92 ounces per ton of silver, and 0.016 ounces per ton of gold. These concentrates were produced from approximately one thousand tons of ore, most of which was removed from raises on the Main Tunnel level.

Only minor exploratory drilling was undertaken from 1947 to 1967. Intermountain Exploration Company drilled two diamond drill holes totaling 601 feet from the Main Tunnel level about 450 feet from the portal during June and July, 1961. In August, 1963 Boyles Brothers Drilling Company completed a 723.6-foot vertical hole from the surface northeast of the mine. During March and April 1964 Callahan Mining Company drilled an angle hole from the Haulage Tunnel. The hole was drilled to the west to a depth of 1.132 feet at a 40 degree angle from vertical.

In May, 1967 Phillips Petroleum Company optioned the property from the Squaw Peak Copper Mining Company for a term of ten years. Phillips conducted an exploration program which included 16,206.5 feet of diamond core drilling, 2756 feet of rotary drilling, 43,000 line-feet of induced polarization surveys, and 6500 feet of reflection seismic lines. Phillips terminated their option on the property in May, 1973 after a total exploration expenditure of $269,736.

In August, 1973 an option agreement was reached between the Squaw Peak Copper Mining Company and Essex International, which permitted Essex to explore the property for six months. A ten year lease-option agreement was made in February, 1974 which gave Essex sole exploration rights until 1984. The present contract is renewable in February, 1975. Essex currently owns exploration rights of 153 claims on the Squaw Peak prospect. Essex has committed approximately $53,000 to date on the Squaw Peak property (August 1974).

## Regional Geology

The Squaw Peak area lies on the northeast perimeter of the basin and range physiographic province. The Mogollon Rim, approximately seven miles east of Squaw Peak, on the northeast flank of the Verde Valley, represents the southern extremity of the Colorado Plateau province. Structural deformation and erosion have created the Verde River Valley, a transition zone between the two provinces.

Rocks of Precambrian to Quaternary age outcrop in central Arizona. Precambrian rocks in Arizona are subdivided into Older and Younger Precambrian. The Older Precambrian in the Squaw Peak region is represented by a metamorphosed intermediate to mafic volcanic complex. These rocks underwent mild to intense structural deformation and low to intermediate regional metamorphism during the Mazatzal Revolution, ending the Older Precambrian (Wilson, 1936). The Mazatzal disruption culminated with a batholithic invasion of granitic to gabbroic composition. This intrusive activity probably produced a huge mountainous region, the roots of which are unconformably overlain by Paleozoic strata.

A long hiatus exists between the Paleozoic sedimentary rocks and Tertiary rocks of sedimentary and volcanic origin. Intrusive dikes and plugs of Laramide (?) age are exposed locally. Widespread late Tertiary alkali-olivene basalt covered the entire region, extending south from the Colorado Plateau. Two periods of extrusions were separated by a period of faulting and uplift of the Colorado Plateau province (McKee and Anderson, 1971). Considerable uplift of the Black Hills during this period is demonstrated by Tertiary movement along the Verde fault zone along the northeastern front of the range. The Verde River valley was created during this period. The development of the valley was interrupted by the formation of a volcanic dam and the subsequent accumulation of lake deposits of the Verde formation (Jenkins, 1923).

The principal structural feature of the region is the Verde fault zone, which extends from Jerome, Arizona southeastward through the Squaw Peak area to approximately fifteen miles south-southeast of the Squaw Peak deposit. The Verde fault is a normal fault which parallels the northeastern base of the Black Hills and dips eastward into the Verde Valley.

The Squaw Peak deposit lies within a broad structurally weak zone known as the Jerome-Wasatch orogen, a north-trending zone extending from Montana to northern Mexico. Copper metallization is known to have ascended at several locations along this zone in the Squaw Peak region, notably at Jerome, Arizona. The Precambrian United Verde massive sulfide orebody at Jerome yielded over 1.8 million tons of copper, in addition to substantial quantities of gold, silver, lead, and zinc. Other Precambrian mineralization in the Black Hills include the Iron King massive sulfide lead-zinc mine at Humboldt, copper-bearing quartz veins at the Yaeger Mine southwest of Jerome, and the Cherry Creek auriferous veins approximately twelve miles north-east of the Squaw Peak deposit. The nearest known occurrence of a major "porphyry copper" deposit is at Copper Basin, Arizona, approximately 40 airline miles west of the Squaw Peak deposit. The Bagdad porphyry copper mine is approximately 80 miles west of Squaw Peak, and the Globe-Miami porphyry copper district is 90 miles to the south-east.

## General Geology

The oldest exposed rocks in the Squaw Peak district are a metamorphosed andesitic volcanic sequence of the Precambrian Ash Creek Group. The Ash Creek Group was originally described from exposures in the northern Black Hills by Anderson and Creasey (1958). Zircon dating of the metavolcanics yields an age of 1820 $\pm$ 10 million years (Anderson, 1971). Due to the absence of well-defined foliation, no estimate is made here of the thickness of the Ash Creek metavolcanic rocks in the Squaw Peak area, although these rocks probably represent several thousand feet of the sequence.

In the Squaw Peak area the Ash Creek Group is intruded by a large Precambrian batholith, which ranges in composition from granite to quartz diorite, with a probable average composition of granodiorite. The granodiorite-metavolcanic contact is characteristically very irregular, probably due at least in part to regional metamorphism which post-dated the granitic intrusion.

The granodiorite is intruded immediately east of the old Squaw Peak Mine by a quartz monzonite porphyry stock which forms an irrugular outcrop of 300 to 400 feet in diameter. Numerous dikes of quartz monzonite porphyry extend in a north-south direction from the parent stock. Surrounding the intrusive quartz monzonite porphyry is a zone of strong quartz-sericite alteration and associated low-grade copper and molybdenum mineralization. Less porphyritic quartz monzonite rocks which are texturally and compositionally similar to the quartz monzonite porphyry stock are exposed primarily as northwest-trending dikes near the contact of the Precambrian granodiorite and the Ash Creek metavolcanics. The intrusion of these dikes in two particular areas along the granodiorite-metavolcanic contact has apparently resulted in the formation of two irregularly shaped breccia zones. Locally strong brecciation, quartz stockworks, and copper-bearing quartz veins and fractures are spatially related to small dikes of fine grained porphyritic quartz monzonite.

The mineralized granodiorite was dated by Phillips Petroleum using the potassium-argon method and was shown to be 1.643 billion years old. This age date is not believed to represent the time of mineralization, in which case the Squaw Peak deposit would be considered as a geologically unique occurrence, with respect to the ages of other known porphyry copper deposits in the southwestern United States. Until further age determinations are made, the ages of the quartz monzonite porphyry and of the mineralization are assumed to be Laramide, or approximately 65 million years old.

Relatively horizontal Paleozoic sedimentary rocks from 200 to 1600 feet in thickness are exposed at the western margins of the Precambrian exposures. These rocks were eroded from the central part of the Verde River valley prior to Tertiary volcanism. The base of the Paleozoic section west of the Verde fault zone is in most places about 5000 feet in elevation; however, a series of step faults in the southern portion of the mapped area have significantly lowered the base of the Paleozoic rocks. Large blocks of the Paleozoic section are also exposed immediately east of the Verde fault zone, in contact with Precambrian rocks. The exposure of Paleozoic rocks in the hangingwall of the fault range from 0 to 1500 feet in thickness. The vertical separation of the Paleozoic rocks by the Verde fault exceeds 1000 feet throughout the area and locally may exceed 3000 feet. The lowest Paleozoic unit in the Squaw Peak area is the Tapeats(?) formation of Cambrian age. The Tapeats is a coarse-grained sandstone which grades upward into dolomitic limestone of the Devonian Martin formation.

Several hundred feet of basalt flows of the Tertiary Hickey formation are deposited on the erosional surface of the Martin limestone. The thickest exposure of the basalt forms the prominent pinnacle known as Squaw Peak. The Hickey basalt is exposed to a limited extent east of the Verde fault, where it overlies the Martin formation in the downthrown block of the fault zone.

A series of low-rounded hills which lie directly east of the Verde fault in the Squaw Peak Mine area represent a sedimentary sequence of the Hickey formation. The Hickey sedimentary deposits in the Squaw Peak area contain primarily rounded limestone fragments up to boulder size of the Martin formation. Lesser amounts of unconsolidated Tertiary basalt, Tapeats(?) sandstone, and Precambrian rocks are also exposed.

Weakly to moderately consolidated limestone, siltstone, and conglomeratic limestone and siltstone of the Verde formation are exposed locally in the drainages east of the Verde fault. These rocks were first described by Jenkins (1923). The Verde formation was deposited during the Pleistocene epoch as lake beds and associated fluvatile deposits throughout the upper Verde River valley.

The youngest unit in the area, other than alluvium, is a large rhyodacitic extrusive rock which outcrops in a group of prominent hills in the northeastern portion of the mapped area. The volcanic center penetrates an exposure of the Verde formation in Squaw Peak canyon. Elsewhere, rhyolitic flows up to 300 feet in thickness overlie the Verde formation. This is the only known occurrence of Quaternary volcanic rocks in the upper Verde valley region (Twenter and Metzger, 1963).

## Structural Geology

The dominant structural element in the Squaw Peak area is the Verde fault. The Verde fault zone trends north to northwest through most of the mapped area and parallels the base of the Black Hills. The Verde fault zone consists of a main fault and several subparallel and hinge faults. Most of the subordinate faults are east of the main zone, and some are obscured by recent volcanics and alluvium.

The Verde fault is a normal fault with the east side of the zone down with respect to the rocks on the west. Where exposed, the dip of the main fault zone is $40^{o}$ to $70^{o}$ to the east.

The Verde fault zone has been structurally weak from Precambrian to recent times. Field data from the Squaw Peak area is insufficient to define the Precambrian displacement. Precambrian vertical displacement in the Jerome area, twenty-five miles northeast of Squaw Peak, was reported to be as much as 1000 feet (Anderson and Creasey, 1958). The most conspicuous displacement in the Verde fault zone in the Squaw Peak area resulted from movement after the accumulation of the Tertiary basalts which blanket the higher ridges in the western portion of the mapped area. These basalts also outcrop at several locations on the east side of the fault zone. Total vertical displacement after deposition of the Hickey basalt ranges from 1100 to 1350 feet where the basalt is exposed on both sides of the fault. Seismic data east of the Verde fault zone in the vicinity of the Squaw Peak deposit, however, indicate that the vertical displacement of the top of the Paleozoic section may be as much as 3000 feet. No lateral movement along the Verde fault is suggested by field evidence, although a horizontal component may exist.

An apparent recent reversal of the Verde fault is indicated by a slightly higher elevation of the Verde formation east of the fault zone with Precambrian granodiorite on the west. Poorly consolidated gravels of the Hickey formation form a series of hills which are usually 15 to 50 feet higher than the adjacent granodiorite in the upthrown block. It is doubtful that the Verde formation has been eroded at a slower rate than the more massive granodiorite. Moreover, scattered fragments of Precambrian metavolcanic rocks are found on top of the large, prominent outcrop of recent rhyodacite volcanics, indicating that substantial reverse movement may have occurred after the extrusion of the rhyodactite.

The dominant structural grain of the rocks in the area of the Squaw Peak deposit is northwest. Numerous minor fractures trend N30°W to N60°W through the deposit. Granitic breccia dikes, shear breccia dikes, and latite porphyry dikes surrounding the deposit trend N25°W to North. Quartz veins in the vicinity of the deposit generally trend N40°W to N75°W.

The predominant northwest fabric probably represents the effects of a pre-mineralization structural grain which became enhanced during the mineralization stage. Jointing in unmineralized and unaltered granodiorite is strongest in a N40°W to N70°W direction, with dips of 60° to 80° to the southwest. Structural features of both pre-mineral and post-mineral age reflect this northwest-trending, southwest-dipping fabric.

Minor drag folding on the east side of the Verde fault zone is exposed in the canyon sidewalls of Chasm Creek. The folds are apparently reverse drag folds which are related to the recent reversal of the main fault zone. A small exposure of Martin limestone exposed on the south side of the canyon has been dragged downward immediately east of the Verde fault zone. A larger fold in the Martin limestone is exposed on the north side of the canyon east of the fault zone (see Plate 1). This folding may be related to a hinge fault of the main Verde fault zone.

A series of nearly vertical step faults in the area south of the Squaw Peak deposit has displaced the base of the Tapeats(?) sandstone approximately 650 feet. These faults strike generally east-west, or at right angles to the Verde fault. The individual vertical displacements of the step faults range from 30 to 150 feet.

## Mineralization

The primary economic minerals in the Squaw Peak porphyry copper deposit are chalcopyrite and molybdenite. Chalcopyrite occurs in quartz veinlets, in fractures, in small biotite-rich pods, and as disseminated mineralization in the Precambrian granodiorite and the granodiorite-quartz monzonite porphyry contact zone. Bornite is rare. Malachite, chrysocolla, and azurite are present as secondary weathering products of chalcopyrite in a relatively shallow zone of oxidation. The oxide zone varies in thickness from 0 to 100 feet, usually not exceeding 50 feet. Molybdenite occurs with chalcopyrite, mostly in veins and fractures. The strongest molybdenite mineralization is at the margin of the quartz monzonite porphyry intrusive. Pyrite occurs with chalcopyrite and molybdenite as disseminations, in quartz veins and fractures, and in biotite blebs. Preliminary observations suggest that the chalcopyrite, molybdenite, and pyrite mineralization was concurrent. Minor amounts of gold, silver, tungsten, and rhenium are present within the zone of strongest mineralization.

Strong sulfide mineralization is exposed in a north-trending sub-elliptical zone about 1200 feet long and 800 feet wide. The center of this zone is occupied by the quartz monzonite porphyry. The quartz monzonite porphyry stock is sulfide-deficient, except at its perimeter, where a gradational contact with the Precambrian granodiorite is abundantly mineralized. Thus, a barren core is surrounded by a chalcopyrite-pyrite-molybdenite assemblage, which yields outward to a chalcopyrite-pyrite assemblage. Pyrite is relatively low throughout the deposit, and seldom exceeds 2 per cent by volume.

The quartz monzonite porphyry and associated mineralized zone appear to plunge 50° to 60° to the west. Copper mineralization rapidly diminishes both laterally and vertically from this zone.

Copper and molybdenum mineralization outside the strong sulfide zone is restricted principally to veins and fractures which strike predominantly northwest and dip steeply southwest. Sparse copper-bearing veins occur in a northwest-trending zone which is roughly 3500 feet long and 1500 feet wide. The quartz monzonite porphyry is at the southeastern end of this zone. Copper mineralization in the veins is usually chalcopyrite or malachite. Some native copper is present in quartz veins within the Ash Creek metamorphosed volcanics north of the deposit.

Scattered copper mineralization is also exposed in a large brecciated zone about 1500 feet northeast of the Squaw Peak deposit.

The breccia zone is located at the contact between the Ash Creek metavolcanics and the granodiorite, immediately west of the Verde fault. The zone is very irregularly shaped, with a maximum dimension of about 1400 feet. Locally strong stockworks of quartz veins are associated with numerous irregular dikes of fine grained porphyritic quartz monzonite which intrude the zone. These dikes may have induced the brecciation of the granodiorite and metavolcanics. Copper mineralization consists of vein and fracture related malachite and chalcopyrite, and is almost always spatially associated with the fine grained dikes. The brecciation and mineralization are very discontinuous within the zone. The Verde Squaw prospect, which consists of a tunnel driven into the breccia zone, encountered discontinuous mineralization. A 723.6-foot-deep diamond drill hole on the southern edge of the breccia exposure was completed in 1963 by Boyles Brothers. Only weak copper mineralization was reported. A similar breccia zone is located at the granodiorite-metavolcanic contact about one mile northwest of the Squaw Peak deposit.

Sulfide mineralization is present locally within the Verde fault zone. Strong pyrite mineralization in the main shear zone is exposed in the northern portion of the mapped area. Hand samples from mineralized shears within the fault zone contain up to five per cent pyrite. No copper mineralization is indicated in the fault zone.

## Alteration

An erratic alteration zoning is developed around the quartz monzonite porphyry stock. An inner zone of strong silicification and sericitization is surrounded by a larger peripheral zone of fracture-controlled epidote-K-feldspar-calcite alteration. Strong quartz veining and pervasive sericite occur in an irregular, sub-elliptical area of approximately 1400 feet by 1100 feet surrounding the quartz monzonite porphyry. The quartz-sericite zone trends north-south and roughly approximates the zone of strong sulfide mineralization. The central portion of this zone is pervasively silicified, with the strongest silicification in the gradational contact zone between the quartz monzonite porphyry intrusive and the Precambrian granodiorite. Sericitization is strongest towards the center of the zone. Plagioclase feldspars in the unoxidized portion of the quartz-sericite core are altered to an apple green color, which may represent partial or total replacement by sericite.

Enclosing the quartz-sericite zone is a larger area containing an epidote-orthoclase(?)-calcite assemblage, which is confined primarily to northwest-trending fractures and veins. This zone is a maximum of 4600 feet long in a north-northwest direction, and up to 2500 feet wide. Typically, the veins and fractures are zoned outward from epidote ± quartz to an envelope of salmon-colored K-feldspar. Calcite is usually present in the wallrock as thin films on microfractures. The entire assemblage seldom persists over a width of 10 centimeters. Most of the altered veins and fractures in the outer zone strike northwest and dip steeply southwest, probably reflecting the pre-mineralization structural grain. A peripheral quartz-K-feldspar-epidote-chlorite assemblage has been described in the deeper portions of other porphyry copper deposits, including Sierrita, Arizona and Bethlehem, British Columbia (Guilbert and Lowell, 1974).

The spatial and geometrical association of the mineralization and alteration with the quartz monzonite porphyry indicate that this intrusive is responsible for the Squaw Peak deposit. Strong mineralization and alteration are arranged in nearly identical zones surrounding the quartz monzonite porphyry stock. Subordinate outward mineralization and alteration appear to be controlled by a northwest-trending fracture system and by distance from the energy source.

## Exploration Potential

Current information indicates a porphyry copper-molybdenum deposit of low tonnage and grade at Squaw Peak. Exploitation of the Squaw Peak deposit is subject to current and future economic circumstances. Geologic and drilling data have defined a steep-sided, bowl-shaped zone of mineralization and suggest that the mineralization terminates below this zone. A set of maps and ore reserve calculations completed by Essex geologist J. Kenneth Jones are available in the Tucson office.

The quartz monzonite porphyry stock and associated mineralization appear to have been localized at least in part by a northwest-trending fracture system. Drilling data indicates that the quartz monzonite porphyry is an irregular columnar body, plunging 50° to 80° to the west. The structurally weak northwest-trending zone provides the most favorable location for any associated igneous activity at depth below the known Squaw Peak deposit. The existence of a deeper orebody at Squaw Peak is not supported by observations at other known porphyry copper deposits.

The potential for a faulted-off portion of the Squaw Peak deposit within the hangingwall block of the Verde fault zone is geologically intriguing. The Verde fault passes about 1800 feet northeast of the Squaw Peak deposit. The possible presence of a faulted portion of the deposit in the downthrown block of the fault is subject to: (1) the time relationship between the age of mineralization and the movement along the Verde fault; (2) the vertical extent of the Squaw Peak deposit prior to erosion; and (3) the dip of the Verde fault.

The exploration potential in the hangingwall of the Verde fault was considered by Phillips Petroleum geologists. Rotary drilling, conducted by Phillips failed to penetrate the thick Tertiary basalts and sediments in the upper portion of the downthrown block. The deepest drill hole east of the fault zone was to 972 feet and bottomed in Tertiary basalt of the Hickey formation. Induced polarization, ground magnetics, and seismic surveys conducted by Phillips over the hangingwall block were inconclusive. Seismic data indicated, however, that over 2000 feet of alluvium, lake beds, and volcanic rocks overlie the top of the Paleozoic and Precambrian units east of the Verde fault zone.

The age of the copper mineralization is unknown. The youngest rock intruded by the mineralizing quartz monzonite porphyry is the Precambrian granodiorite, which yielded an age date of 1643 million years.

If the mineralization is Precambrian, the target for a faulted segment of the Squaw Peak deposit would be at least 3000 feet deep. Moreover, lateral displacement along the fault may have removed the segment to an unknown distance from the Squaw Peak mine area. It is also conceivable that the currently observed fault zone is a considerable distance west from the zone which was active during the Precambrian.

The relative ages of other porphyry copper mineralization in the southwestern United States suggest that the Squaw Peak deposit was formed during the Laramide orogeny, or from late Cretaceous to mid-Tertiary time. Assuming a Laramide age for the Squaw Peak mineralization, a buried segment of the deposit east of the Verde fault may be less than 3000 feet deep, with no substantial lateral displacement. Providing that the time relationship between the Squaw Peak mineralization and the Verde fault movement is not prohibitive for the preservation of any portion of the original deposit in the fault hangingwall, the vertical extent of the initial orebody would have to be substantially greater than that which is predicted from observed small porphyry copper systems in order to reach the projected Verde fault zone.

The existence of a separate porphyry copper deposit similar to the Squaw Peak deposit is not indicated by geologic examination of the district. The presence of such a deposit may be obscured by Tertiary volcanic and sedimentary rocks and recent alluvium. The structure east of the Squaw Peak mine area is favorable for potentially economic igneous activity; however, the detection of an orebody beneath the thick Quaternary and Tertiary cover would be extremely difficult.

The two breccia zones located at the contact between the Precambrian granodiorite and the Ash Creek metamorphosed volcanic rocks are possible exploration targets. The inhomogeneous nature and the inconsistent copper mineralization suggest that no substantial ore reserves are present in these areas.

The Precambrian Ash Creek metavolcanics are of further exploration interest as a potential host for a massive sulfide deposit. The Ash Creek group served as a host for the historic United Verde orebody, located on the west side of the Verde fault, approximately 25 miles northwest of Squaw Peak. Correlation of the units in the Ash Creek group, however, is extremely difficult due to the complex history of deformation since their deposition. The most extensive surface exposure of mineralization within the metavolcanics is on the west side of the Verde fault zone, approximately 3000 feet north-northeast from the Squaw Peak deposit. The rocks here are strongly fractured, with numerous northwest-trending quartz veins containing malachite, chalcopyrite, and some native copper. The mineralization in this area is probably related to hydrothermal activity which ascended in the Verde fault zone. A 601-foot-deep drill hole, DDH 19, was drilled in this area by Phillips Petroleum, but failed to encounter significant mineralization.

## Summary and Conclusions

Precambrian granodiorite was intruded by a quartz monzonite porphyry stock, probably in Laramide time. The granodiorite subsequently hosted alteration and sulfide mineralization typical of most small porphyry copper occurrences in southwestern North America.

The Squaw Peak copper deposit contains reserves of 11,658,000 tons at a grade of 0.42% Cu, using a 0.3% Cu cut-off grade (Bellum, 1974) and a geologic inventory of 20,000,000 tons at a grade of 0.36% Cu, using a 0.2% Cu cut-off grade (Jones, 1974). Current drilling and geologic data suggest that no substantial ore reserves exist at depth below the presently defined deposit.

Other possible exploration targets in the Squaw Peak area include: (1) the east side of the Verde fault zone; (2) breccia zones; and (3) the Ash Creek group metamorphosed volcanic rocks. The potential for the discovery of additional ore reserves in these areas appears to be remote. If the Squaw Peak property is retained, future exploratory work should include deep drilling concentrating in the center of the known Squaw Peak deposit.

## References Cited

Anderson, C.A., 1951, Older Precambrian structure in Arizona; Geol. Soc. Amer. Bull., v. 62, pp. 1331-1346.

Anderson, C.A., P.M. Blacet, L.T. Silver, and T.W. Stern, 1971, Revision of Precambrian stratigraphy in the Prescott-Jerome area, Yavapai County, Arizona; U.S. Geol. Survey Bull. 1324-C, 16 p.

Anderson, C.A. and S.C. Creasey, 1958, Geology and ore deposits of the Jerome area, Yavapai County, Arizona; U.S. Geol. Survey Prof. Paper 308, 185 p.

Bellum, D.P., 1974, Squaw Peak evaluation report (unpublished) May 5, 1974, 12 p.

Guilbert, J.M. and J.D. Lowell, 1974, Variations in zoning patterns in porphyry ore deposits; Canadian Inst. of Mining Bull., Feb. 1974, pp. 99-109.

Jenkins, O.P., 1923, Verde River lake beds near Clarkdale, Arizona; Am. Journal Sci., 5th ser., v. 5, no. 25, pp. 65-81.

Jones, J.K., 1974, Ore reserve memorandum to Essex International (unpublished).

McKee, E.H. and C.A. Anderson, 1971, Age and chemistry of Tertiary volcanic rocks in north-central Arizona and relation of the rocks to the Colorado Plateaus; Geol. Soc. Amer. Bull., v. 82, pp. 1767-2782.

Twenter, F.R. and D.G. Metzger, 1963, Geology and ground water in Verde valley--the Mogollon Rim region, Arizona; U.S. Geol. Survey Bull. 1177, 132 p.

Wilson, E.D., 1936, Precambrian Mazatzal Revolution in central Arizona; Geol. Soc. Amer. Bull., v. 50, pp. 1113-1164.