THE GEOLOGY OF THE COPPER CREEK AREA, BUNKER HILL MINING DISTRICT, GALIURO MOUNTAINS, ARIZONA

by

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Abstract

Copper Creek is located 14 miles northeast of San Manuel on the western slope of the north-central Galiuro Mountains in the Bunker Hill mining district, Arizona. Copper Creek is important in understanding the porphyry copper system because it furnishes the chance to study the upper-level occurrence of a deep mineralized porphyry copper deposit.

Minor outcrops of Precambrian and Paleozoic sedimentary rocks are found in the eastern and northeastern portions of the district. In the north, west, and south portions is a thick heterogeneous sequence of andesitic and dacitic volcanic rocks designated as Cretaceous(?) Glory Hole Volcanics. Intrusive into these older rocks are three stocks of Copper Creek granodiorite and associated porphyries. Overlying the intrusive rocks are the Galiuro Volcanics, a thick sequence of Tertiary flows, tuffs, and agglomerate. Plio-Pleistocene Gila Conglomerate is in fault contact with the older rocks along the western edge of the district. The Copper Creek stocks consist of an equigranular phase (Copper Creek granodiorite) and a porphyritic phase (dacite porphyry). The porphyritic phase is divided into pink porphyry, feldspar porphyry, and dark porphyry varieties.

The principal structural trends are east-northeast, northwest, and north, expressed by fracturing, veins, faults, and the shapes and alignment of the intrusions and breccias.

Spacially and chronologically associated with the dacite porphyry are breccia pipes. Gensis of the breccias is closely linked with emplacement of the dacite porphyry stocks. Intersecting structures localize and control the emplacement of the porphyries and the shapes of the breccias.

Significant porphyry copper mineralization is present in the American Eagle basin located in the south-central portion of Copper Creek. The copper mineralization occurs 2,000 feet or more below the surface in an area of relatively intense veining and clusters of breccia pipes and dacite porphyry plugs. The deposit is a low-sulfide system averaging approximately 3 percent by weight total sulfides. In the upper portions, the sulfide is predominantly pyrite, which grades downward into the predominantly chalcopyrite zone. Bornite and some molybdenite occur at the base and below this zone. The mineralization shows strong fracture and breccia control throughout the system.

Zones of pervasive alteration are not well defined at Copper Creek. In the American Eagle basin sericite is the dominant alteration product. It is associated with the breccia pipes, veins, and many of the dacite porphyry plugs. Potassic and argillic alteration occur as scattered zones, along with lesser amounts of tourmalinization, silicification, and propylitization.

Introduction

Copper Creek, located on the western flank of the north-central Galiuro Mountains, 50 miles north-northeast of Tucson, Arizona, is part of the Bunker Hill mining district. History of exploration and mining activity at Copper Creek began in 1863 with the first recording of mining claims. First mining was for lead and silver at the Blue Bird mine. In 1883, the Bunker Hill mining district was organized and recorded. The first copper exploration began with the Table Mountain Copper Company in

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1897-98. From 1903-1917 prospecting and some production was done at the Old Reliable and other breccia pipes by the Copper Creek Mining Company. The Calumet and Arizona Mining Company did exploration work in northwest Copper Creek from 1907 to 1909. In 1933 the Arizona Molybdenum Corporation obtained the Childs-Aldwinkle mine, which produced until 1938, when mining activity in the district ceased. During this time, total known metal production was over 8 million pounds copper, nearly 7 million pounds molybdenite, over 4 million pounds lead, and in excess of 200,000 ounces silver and 726 ounces gold.

Early copper exploration efforts in the Bunker Hill mining district were concentrated on the mineralized breccia pipes. The first exploration for a porphyry copper-type deposit by deep drilling was done during the middle 1960s by Bear Creek Exploration. Newmont began its exploration effort at Copper Creek in 1966 and was joined in 1971 by Exxon.

Geologic work in and adjacent to the Copper Creek area was done by Kuhn (1941), Creasy, Jackson, and Gulbrandsen (1961), Simons (1964), and Krieger (1968). Information on individual mines or breccia pipes was published by Weed (1913), Kuhn (1938), Denton (1947), Joralemon (1952), and Simons (1964).

Geology

Figure 1 shows the general geology of the Copper Creek area. The Galiuro Mountains are a north-northwest-trending, elongate range along the eastern edge of the San Pedro Valley and are formed mostly of gently east-dipping Tertiary volcanic rocks. Pre-Tertiary rocks underlying the volcanics are exposed along the northwestern flank of the Galiuro Mountains. Copper Creek Canyon cuts into and across the southern portion of these older rocks exposing Precambrian and Paleozoic sedimentary rocks and Mesozoic to lower Tertiary volcanic and intrusive rocks. Plio-Pleistocene semi-consolidated fanglomerate is in fault contact with the western edge of the district.

Pre-intrusive Rocks

Exposures of pre-intrusive rocks occur in the eastern portions of the district. Precambrian Apache Group sedimentary rocks (Dripping Spring Quartzite and Mescal Limestone) with basal Paleozoic sedimentary rocks (Bolsa Quartzite) are found in the southeastern portion. This block of north-south-striking, moderately west dipping units is covered by volcanics to the east and south and is intruded on the north and west. In the east and northeast are broadly folded Paleozoic rocks (Bolsa Quartzite, Martin Formation, Escabrosa Limestone) and Mesozoic rocks (Pinkard Formation). Volcanic rocks overlie them to the north and east and intrusive rocks cut the exposures to the west and south.

Much of the western half and part of the southern edge of the mapped istrict is Cretaceous(?) Glory Hole Volcanics. This rock group comprises a heterogeneous pile of andesitic to latitic tuffs, welded tuffs, breccias, lavas, and flow breccias. They lie unconformably on Paleozoic and Precambrian sedimentary rocks and are overlain by Tertiary volcanics. Thickness of the volcanics is unknown. Thermal metamorphism from adjacent intrusive stocks has strongly modified the volcanic rocks into a dark-gray to black, dense, very fine grained, crystalloblastic-hornfelsic rock. Only on weathered surfaces are the primary volcanic textures sometimes visible. Relict flow features, occasional interbedded lenses of quartzite, and minor fresh-water limestones suggest that the volcanics strike northwest and dip gently to the northeast.

Intrusive Rocks

The Copper Creek granodiorite and associated porphyries intrude the older sedimentary and volcanic rocks. The Copper Creek granodiorite occurs in three northwesterly aligned stocks: the northwest Dry Camp stock, the central Copper Creek stock, and the southern Sombrero Butte stock. Much of the eastern half of the mapped area is the Copper Creek stock.

Copper Creek granodiorite is gray to light gray, medium to fine grained, hypidiomorphic-granular to slightly porphyritic. It consists of 5 to 20 percent orthoclase, 40 to 50 percent plagioclase, 15 to 20 percent quartz, and 5 to 6 percent biotite. Hornblende is occasionally present but is generally replaced by biotite.

Porphyritic intrusive rocks occur as plugs and dikes and are generally clustered within three northwest-trending zones (eastern, central, and western portions of the area). They intrude all previously described rocks. Petrographically, the porphyries have been grouped into diorite porphyry and dacite porphyry. The diorite porphyry is dark gray and consists of fine-grained plagioclase, hornblende, and minor quartz. This rock type is not common and may represent an earlier phase of the granodiorite.

The dacite porphyry group has been divided into three subtypes based on field classification: pink porphyry (eastern porphyry zone and partially in southern portion of central zone);

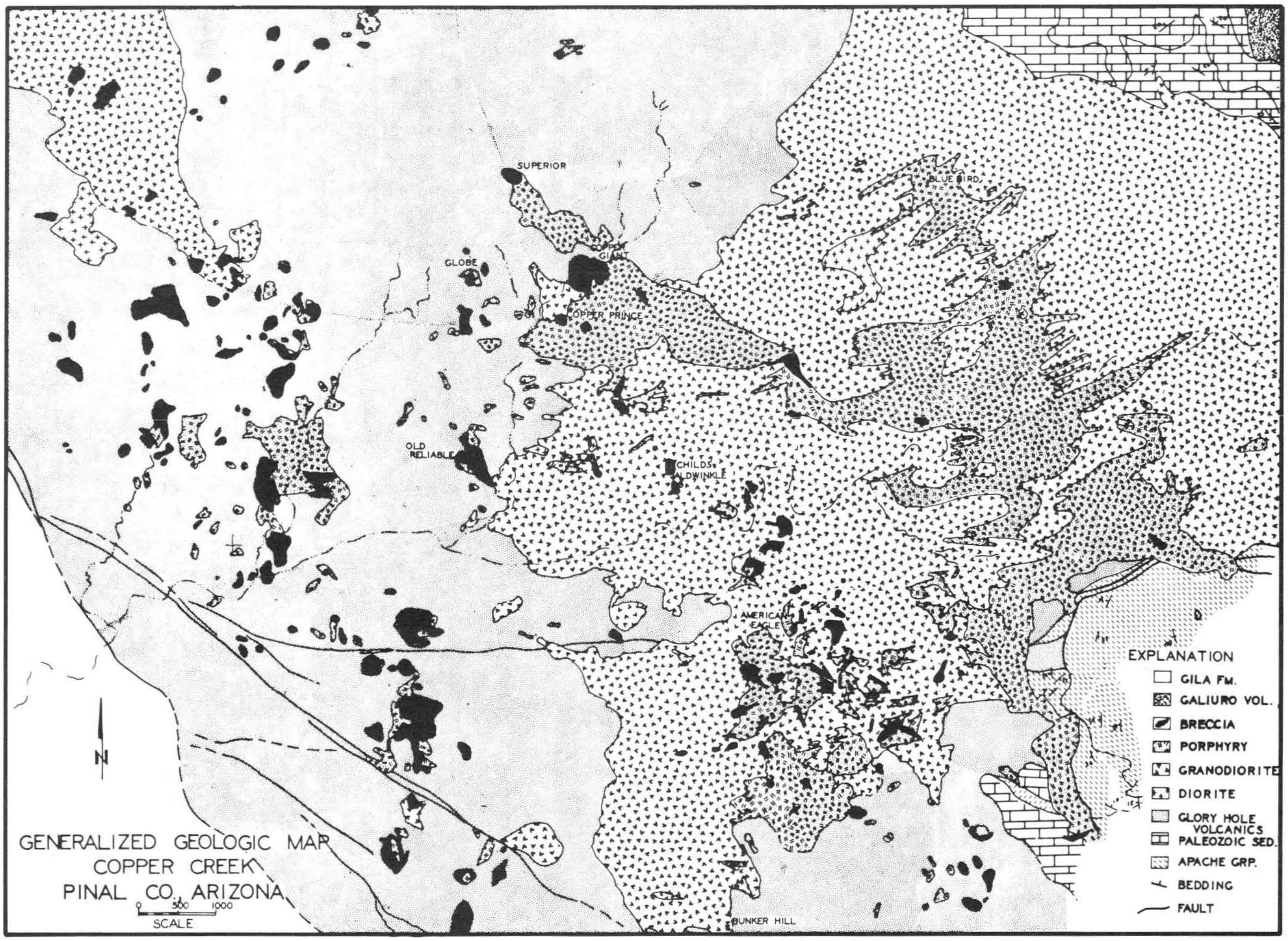

Fig. 1. Generalized geologic map, Copper Creek, Pinal County, Arizona

feldspar porphyry (central zone); and dark porphyry (western zone, 60 percent southern portion of central zone, and less than 5 percent of eastern zone).

Pink porphyry is light pink and has a quartz monzonite composition. It is composed of medium-grained plagioclase (10-15%) and minor biotite (less than 5%) phenocrysts set in a fine-grained, aplitic matrix of quartz and orthoclase.

Feldspar porphyry is gray and has a granodiorite composition. Mineralogically, the porphyry comprises 50 to 65 percent medium-grained plagioclase, up to 5 percent biotite, and occasional rounded quartz phenocrysts set in a fine-grained, xenomorphic groundmass of orthoclase, plagioclase, and quartz. The plagioclase phenocrysts are blocky and somewhat crowded.

The dark porphyry is gray to dark gray and varies from near quartz diorite to granodiorite. Medium-grained phenocrysts of plagioclase (10 to 30%), biotite (5%), and rare rounded quartz are set in a fine- to very fine grained, xenomorphic to felty matrix of plagioclase, quartz, biotite, and orthoclase.

These rocks have been dated by the K-Ar method using biotite. The dates are: granodiorite, 64-68 m.y.; pink porphyry, 59-62 m.y.; and dark porphyry, 52-53 m.y.

Breccia Pipes

Numerous vuggy, highly altered breccias are adjacent to or involved with the dacite porphyries of Copper Creek. These masses have been given the general term "breccia pipes" as several are known to have a near-vertical long dimension. The most common dacite porphyry variety associated with a breccia pipe is dark porphyry. Feldspar porphyry has some breccias associated, but there is none known with the pink porphyry.

Breccia pipes range in size from a few tens of feet to over 600 feet and vary in plan from equant to elongate to irregular. Underground mapping and limited drill data indicate the third dimension of some of them. Shapes indicated are (1) carrot-shaped—breccia flaring upward and tapering downward; (2) two or more aligned breccias coalescing into a single pipe with depth; (3) breccia pinching out into a vein in less than 1,000 feet; and (4) location of lensoid, sheetlike breccia bodies along steep or flat fractures or contacts. Cross sections constructed from drill data, along with surface mapping suggest that some breccias are persistent to over 3,000 feet in depth and that others do not reach the present surface but are blind pipes.

Breccia pipes consist of pebble- to cobble-size, angular to subangular to locally rounded fragments derived from the surrounding wall rock. There appears to be no or very little mixing of rock types. Fragments can vary greatly in size, shape, and texture within a single breccia mass. A zone of well-rounded fragments can occur within a matrix of angular to subangular fragments. Often very large, unbroken blocks up to 100 feet are found surrounded by pebble- to cobble-size fragments. Sometimes the fragments are platy or oblong and are aligned such that a crude layering is apparent. This layering may be interior to the breccia or subparallel to its walls.

Fragments vary from completely altered to quartz-sericite to having a thin rim of quartz-sericite. These fragments can be tightly packed such that intrafragmental areas are absent or minor. Packing in other breccias may be such that large, vuggy areas exist. Intrafragmental areas may be completely filled or may have only minor material present. Quartz-sericite and crystalline quartz are common intrafragmental material. Other materials are tourmaline, pyrite, chalcopyrite, specularite, quartz-orthoclase, and coarse biotite. They may occur separately or in various combinations. The nature of the original intrafragmental filling is unknown.

Contacts between breccia pipes and wall rock are often sharp and generally steep. Wall rock at the contact may exhibit 2-10 feet of closely spaced fractures parallel to the contact or a 1- to 3-foot zone of strongly crushed and moderately altered rock. Alteration of the surrounding wall rock may be limited to a few feet or may extend tens of feet beyond the breccia contact.

Formation of a breccia pipe is associated with the dacite porphyry intrusive rock, based on their close spacial and temporal relationships. Jointing has influenced the location and shapes of the intrusive and breccia bodies. Where several joint sets intersect, a zone of weakness is produced. These zones act as conduits for the emplacement of porphyry plugs and dikes, and forces generated during emplacement cause intense fracturing and brecciation adjacent to and above the porphyry body. These areas of intense fracturing serve as channelways for hydrothermal solutions, which can enhance the breccia texture through alteration and leaching of the fragments. Collapse and additional development of the column of brecciated rock could be promoted through other possible mechanisms, e.g., magma pressure fluctuations, repeated porphyry intrusions, or volume reduction of porphyry by water loss and crystallization. The formation of breccia pipes may result from a number of interrelated processes, and the internal variations between individual breccias only reflect the degree to which a single mechanism functioned during development.

Overlying all previously discussed rocks are the Miocene Galiuro Volcanics. They occur north, east, and south of the area and consist of several thousand feet of andesitic and rhyolitic welded tuffs, flow, ash tuffs, and agglomerates (Simons, 1964; Krieger, 1968). The Plio-Pleistocene Gila Conglomerate is mapped along the western edge of the area. This unit has been faulted down to the west against the older crystalline rocks.

Structure

Joints and veins are the principal structural features mapped. Foliation within the intrusions is almost absent. Rose diagram plots of steeply dipping joints and veins exhibit two major directions, S. 85° E. to N. 70° E. and N. 0° E. to N. 15° W., and two lesser directions, N. 20° W. to N. 55° W. and N. 15° E. to N. 40° E. Flat joints are common at various places in the district. Veining occurs almost wholly in the east-west structural direction. Intrusion and breccia shapes and alignments often exhibit the influence of one or more of these structural directions.

Alteration

A deep porphyry copper system occurs beneath the American Eagle basin. This basin is a topographic feature just south of Copper Creek and is located in the south-central portion of the area. Study of mineralization and alteration of this porphyry copper system is still in its preliminary stages. However, it is apparent that this deposit is a relatively high level, possibly vented porphyry system. Main evidence for shallow emplacement is the abundant breccia pipes and lack of well-defined pervasive alteration zones.

Well-developed, pervasive alteration patterns are not easily recognized on the surface at Copper Creek. Much of the alteration is confined to vein selvages, breccia pipes, and dacite porphyry plugs and their margins. However, some alteration aspects for the different rock types can be generalized. In the Precambrian and Paleozoic sedimentary rocks, the carbonate rocks exhibit the greatest effect. They are mostly recrystallized, with some local argillization and limited calc-silicate development. The Glory Hole Volcanics exhibit pervasive propylitic alteration and silicification with abundant pyrite, especially adjacent to vein sets and where intruded by a cluster of dacite porphyry plugs. Weak, pervasive propylitic alteration with local areas of superimposed potassic and phyllic alteration is common for the granodiorite. Dacite porphyry shows weak to strong phyllic alteration. Very strong phyllic alteration with silicification and local tourmalinization is exhibited by most breccia pipes.

In the American Eagle basin, the rocks contain higher sericite and quartz and lower total feldspar than rocks outside the area. Potassic alteration occurs primarily as the addition of orthoclase by veinlets, vein selvages, or metasomatic replacement. At the surface, potassic alteration is spotty. However, the amount of potassic alteration increases with depth below the basin and a "floor" of fairly intense pervasive potassic alteration underlies the zone of copper-rich mineralization.

Phyllic alteration predominates at the surface in the American Eagle basin. It is confined to vein selvages, breccia pipes and some of the dacite porphyry plugs and their margins; vein selvages are the most common and exhibit well-developed zoning. Quartz-sericite typically borders the quartz-sulfide veinlet. This assemblage grades outward to a quartz-sericite-chlorite zone and to an outer zone of sericite-argillite. This outer zone is characterized by the presence of cloudy to waxy, light-green plagioclase. The alteration product is a mixed mica comprised of sericite, montmorillonite, kaolinite, and illite. With depth the phyllic alteration decreases due to the diminishing size of sericite selvages. This decreasing phyllic alteration and increasing pervasive potassic alteration with depth form an overlapping zone of mixed alteration. Combination of complex vein selvages, i.e., sericite and orthoclase, and the mixed zone of alteration suggest the overprinting of phyllic alteration onto potassic alteration. In the lower portion of the mixed alteration zone and just into the area of intense potassic alteration occurs the zone of significant copper mineralization. There is some suggestion that propylitic alteration may occur below the potassic alteration. Rock from a deep drill hole in the central portion of the American Eagle basin exhibits weak sericite and secondary orthoclase with stronger chlorite-epidote alteration.

Two special alteration minerals, tourmaline and anhydrite, occur at Copper Creek. Tourmaline, schorl variety, is present districtwide and appears to be limited to the upper levels of the deposit. It occurs as acicular crystals in breccias, along veinlets, in quartz-sericite selvages, and as blebs or rosettes in dacite porphyry. Tourmaline may occur alone or may be associated with quartz and pyrite. Purple and white anhydrite is common in the deeper chalcopyrite mineralized zones, occurring as disseminated masses and veinlets.

Mineralization

Significant copper mineralization occurs 2,000 feet or more beneath the surface of the American Eagle basin. It covers an elliptic area approximately 2,500 feet east-west and 1,500 feet north-south. The copper zone underlies a relatively intense east-northeast-trending fracture zone and is associated with a cluster of breccia pipes and dacite porphyry intrusions. Mineralization is hypogene as there is only surficial oxidation and no supergene enrichment. An exception to this is the breccia pipes where oxidization and leaching may occur 100 to 200 feet in depth.

The copper porphyry system at Copper Creek is a relatively low sulfide system in comparison with most Southwest porphyry systems. Dominant sulfides are pyrite and chalcopyrite. Minor amounts of bornite and molybdenite are present in the deeper portion of the system, and galena and sphalerite have been noted in the periphery. Sporadic occurrences of specularite have been noted, especially in some breccias and strongly altered zones. Within the system there is a pronounced vertical zoning of sulfides. Pyrite with very minor chalcopyrite is the principal sulfide in the upper portions of the deposit. With depth, pyrite diminishes and chalcopyrite becomes dominant. Within the copper-rich zone, chalcopyrite is the principal sulfide. At the base of the system, bornite appears and may form up to half of the sulfides. Some high-level chalcopyrite and occasional bornite does occur at Copper Creek and is associated directly with certain breccia pipes.

Surface expression of mineralization at Copper Creek is not overly impressive. Granodiorite and dacite porphyry host limonite-stained breccias and are cut by oxidized quartz-pyrite veins. Visible copper oxides are rare, although geochemically anomalous amounts of copper are found in the veins and breccias.

Sulfide mineralization in the Copper Creek porphyry copper system is controlled primarily by fractures. Other noted mineralization occurrences are disseminated sulfides in quartz-sericite and some porphyries and sulfides as intrafragmental fillings in breccias. In the upper portion of the system, veins are steeply dipping, but with depth nearly horizontal veins become abundant. Rapid decrease in both fracture density and total sulfide content marks the base of the copper-rich zone.

Summary

Copper Creek is the location of past exploration, moderate mine production, and recent discovery of a deep porphyry copper system. Geologic work to date has furnished a preliminary understanding of the igneous activity, hydrothermal alteration patterns, and mineralization within this district. Interpretation of this knowledge forms the basis for the continuing exploration. Copper Creek is important to the understanding of porphyry copper systems because it furnishes a chance to study the upper level occurrence of a deep mineralized porphyry copper deposit.

During Laramide time Precambrian and Paleozoic sedimentary and Mesozoic volcanic rocks of the Copper Creek area were intruded and thermally altered by three granodiorite stocks. The central Copper Creek stock is the site of later dacite porphyry intrusions and related hydrothermal alteration and mineralization. These porphyries occur in and west of the granodiorite stock as plugs and dikes crudely grouped in three northwest-trending zones.

The early pink porphyry appears to be a hydrous potassic and siliceous end member of the granodiorite. There are no known breccias associated and very minor copper mineralization present with this dacite porphyry variety.

Dark porphyry and feldspar porphyry are younger dacite porphyry varieties with which the alteration, mineralization, and breccia pipe development are closely associated. These porphyries occur as plugs, often forming a cluster, and were intruded over a period of time. The location, shape, and clustering patterns of these plugs were influenced by northwest, east-west, and less prominent north-south and northeast structural zones.

The forceful injection of these porphyries into brittle rock caused intense fracturing and brecciation above and adjacent to the plug. This is indicated by the occurrence of intrusion breccias and breccia pipes adjacent to many of the dacite porphyry intrusions. Contemporaneous development of intrusions and brecciation, probably by multiple injections, is shown by the occurrence of porphyry in breccia both as fragments and dikes. Some additional brecciation may be caused by collapse due to volume reduction through magma pressure fluctuations or its crystallization. These zones of fracturing and brecciation became channelways for later hydrothermal solutions. In this manner additional breccia development and textural enhancement occurred by alteration and leaching.

The American Eagle Basin, an area of strong surface alteration and containing a cluster of breccia pipes and dacite porphyry plugs, is where the deep zone of porphyry copper mineralization occurs. In this system the principal alteration and mineralization are fracture controlled. Superimposed on this is the less prominent, but spectacular mineralization controlled by breccia pipes and porphyry plugs. Initial hydrothermal alteration appears to have been potassic. With time and changing hydrothermal fluid composition, the alteration shifted into the phyllic field. This is indicated by the complex vein selvages where potassic alteration often borders the interior sericitic alteration, and the overlapping of serictic alteration onto increasing potassic alteration with depth in the American Eagle basin.

Mineralization in the American Eagle basin exhibits a strong vertical zonal pattern. Pyrite is the dominant sulfide in the upper portions of the porphyry system. With depth chalcopyrite increases to where it is the principal sulfide. Deep within the system bornite occurs. Significant copper mineralization is found in the lower mixed alteration zone and upper potassic alteration zone. Breccia pipes distort this picture somewhat by bringing chalcopyrite and some bornite mineralization high into the system.

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