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SOME GEOLOGIC FEATURES OF THE SUPERIOR AREA, PINAL COUNTY, ARIZONA

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With a Section by —

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INTRODUCTION

The Superior area spans part of the rugged terrain between the western margin of the Pinal range and the alluviated desert valleys of central Arizona. This area may be considered part of the Superstition Mountains. It extends about 18 miles in a north-south direction and 7 miles in an east-west direction, centered about the town of Superior.

Here, the topographic expression of structural features is spectacular. The north-south trending Kings Crown Peak-Apache Leap escarpment divides the area into two major topographic units. East of the escarpment is an upland capped by welded dacitic tuff. West of the escarpment, erosion, acting upon faulted basement blocks and thick accumulations of eruptive rocks, has produced a rough terrain at lower elevations. The mining community of Superior is situated in a fault-formed basin in the central part of the area. Rugged landscape southwest of Superior is commanded by Picket Post Mountain, which is an eroded volcanic vent; the remnant of a once extensive volcanic pile.

Within the Superior Area, elevations range from 2400 feet in the bed of Queen Creek near the William Boyce Thompson arboretum, to 5630 at the crest of a prominence near Kings Crown Peak. Queen Creek, the intermittent major drainage of the area, heads in the high country east of the Kings Crown Peak-Apache Leap escarpment and flows westward, periodically gathering floodwaters from most of the surrounding region.

This paper is presented as a review of some of the more interesting geologic features of the Superior area. The basic framework of the geology was presented by Ransome (1903, 1919), Darton (1925), and other early workers. Short and others (1943) presented a complete report on mineralization and mining activity to that date. More recently, studies by Shride (1958), Krieger (1961), and D. W. Peterson (oral communication) have contributed much to our understanding of the relationships between the Precambrian and the Cambrian sedimentary rocks, and the nature and age of the diabase intrusions in the vicinity of Superior. Recent mapping by Peterson (1960, 1961) in the Haunted Canyon and Superior quadrangles has lead to an understanding of the nature of, and a possible source for, the great thicknesses of rhyolitic and dacitic volcanic rocks in the northern and eastern parts of the area. Lamb has studied an area between the Superior quadrangle and the Gila River, and has contributed to this paper a discussion of volcanism southwest of Superior. D. W. Peterson has mapped the geology of the Superior quadrangle, and the result of his investigation is being published as U. S. Geological Survey Mineral Investigations Field Studies Map MF-253 (in press). Description of rock units, except for the later volcanic rocks described by Lamb, are from Peterson (1960, 1961, oral communication).

The generalized geology of the area is shown by the accompanying geologic map and sections (in pocket).

PRE-MESOZOIC ROCK UNITS, RELATIONSHIPS AND DISTRIBUTION

Early Precambrian Rocks

Pinal Schist is the oldest rock within the Superior area. This metamorphosed basement rock crops out over a large area north of the Concentrator fault and west of Kings Crown Peak. West and south of Picket Post Mountain, Pinal Schist lies beneath later volcanic rocks. In the Magma Mine, workings have penetrated more than 1300 feet into Pinal Schist.

A quartz diorite intrusive mass crops out at the head of Wood Camp Canyon. Peterson (1960) assigned this rock to the Early Precambrian because it shows intrusive relationships with Pinal Schist but not with Scanlan Conglomerate.

Ruin Granite crops out in the northwest corner of the Superior area. This Early Precambrian rock probably intruded Pinal Schist, but relationships with the quartz diorite are not known.

Late Precambrian Rocks

Unconformably overlying Pinal Schist is the Apache Group, a conformable sequence of sedimentary and volcanic rocks. These are, in ascending order, Scanlan Conglomerate and Pioneer Formation (400 feet thick), Barnes Conglomerate and Dripping Spring Quartzite (650-800 feet thick), Mescal Limestone (0-350 feet thick, and basalt (0-320 feet thick). Troy Quartzite (0-730 feet thick), recently demonstrated to be of Late Precambrian age (Shride, 1958, Krieger, 1961, Peterson oral communication), disconformably overlies the basalt of the Apache Group.

The Apache Group and Troy Quartzite have been injected extensively by diabase, which is also of Precambrian age (Shride 1958, Krieger 1961, Peterson oral communication). These diabase intrusions are generally sills, and aggregate more than 3000 feet in thickness in the Magma Mine. They produced a drastic inflation of the sedimentary section, and were apparently accompanied by substantial deformation. The highly variable thicknesses of Mescal Limestone, basalt, and Troy Quartzite in the Superior area are due principally to deformation and erosion at the end of Precambrian time (Peterson, oral communication).

Rocks of the Apache Group and diabase crop out along the Kings Crown Peak-Apache Leap escarpment, maintaining a moderate eastward dip. Vertical and overturned beds are present at the head of Wood Camp Canyon. Apache Group rocks with vertical and steep eastward dips also crop out beneath the later volcanic rocks south of Picket Post Mountain. Troy Quartzite is absent locally north of Superior.

Paleozoic Rocks

Rocks of Cambrian age (0-300 feet thick), Devonian Martin Limestone (350-400 feet thick), Mississippian Escabrosa Limestone (500 feet thick), and Pennsylvanian Naco Limestone (0-1400 feet thick) overlie one another with remarkable parallelism, although Cambrian and Devonian formations are separated by a hiatus spanning Ordovician, Silurian, and part of Devonian time, and Mississippian and Pennsylvanian formations are separated by an interval of erosion.

Cambrian rocks were deposited upon weathered diabase, eroded Troy Quartzite, and rocks of the Apache Group. The intervening unconformity is a surface of considerable relief; abrupt variations in the thickness of the Cambrian rocks is due chiefly to the irregularity of the surface upon which they were deposited (Peterson, oral communication).

According to Krieger (1961, p. C-163), stratigraphic sections between the Little Dragoon Mountains and Sierra Ancha show that the Cambrian rocks become thinner, and the Abrigo Formation becomes progressively more sandy northward. Krieger (oral communication) suggests that the Bolsa Quartzite is not present as far north as Superior, and that Cambrian rocks in the Superior area are correlative with the Abrigo Formation in the Holy Joe Peak quadrangle. As this correlation has not yet been established definitely, Peterson (oral communication) groups Cambrian strata in the Superior area under the term "rocks of Cambrian age."

Pre-Whitetail erosion cut deeply into Naco Limestone, the youngest Paleozoic formation preserved in the Superior area, and stripped it from most of the area north of the Conley Spring fault.

Paleozoic sedimentary rocks crop out along the Kings Crown Peak-Apache Leap escarpment, where the beds maintain a fairly uniform 30 to 45-degree eastward dip.

MESOZOIC(?)-TERTIARY ROCKS NORTH AND EAST OF SUPERIOR

Mesozoic(?) Intrusive Rocks

In the vicinity of the Silver King Mine, a quartz diorite stock intruded the Naco Limestone and all older rocks. Whitetail Conglomerate overlies an erosion surface cut into this igneous body.

A diorite porphyry plug intruded the quartz diorite at the Silver King Mine, and minor diorite porphyry dikes and sills crop out along the Kings Crown Peak-Apache Leap escarpment. Highly altered dike material is present underground in the Magma fault and subsidiary faults. Because of pervasive alteration, the original composition of this dike-rock is obscure, but it may be equivalent to the diorite porphyry bodies exposed at the surface.

The exact age of these intrusive bodies is not known, but they are definitely older than the surface upon which Whitetail Conglomerate accumulated. Peterson (oral communication) has designated them Mesozoic(?).

Tertiary Rocks

Whitetail Conglomerate overlies quartz diorite and all older rocks. The Whitetail (0 to about 350 feet thick) was deposited within depressions on an erosion surface of considerable relief. Peterson (1960) notes that fragments and matrix seem to have been derived locally. This terrigenous sediment crops out north of Wood Camp Canyon, and sporadically along the Kings Crown Peak-Apache Leap escarpment. Ransome (1919, p. 68) assigned to the Whitetail a probable Early Tertiary age near Ray.

North of the Conley Spring fault, near the headwaters of Wood Camp Canyon, and along much of the course of Haunted Canyon, there is sequence of rhyolite and perlitic obsidian (0 to about 2000 feet thick) that Peterson (1960) termed "earlier volcanic rocks." Peterson (1960) reports:

> The earlier volcanic rocks were erupted as successive flows and pyroclastic outbursts . . . . In this area they covered parts of the same erosional surface upon which the Whitetail conglomerate was accumulating . . . Several rhyolitic bodies that probably represent plugs or small domes occur within the unit . . . .

Quartz monzonite porphyry crops out as a prominent ridge between Wood Camp Canyon and Haunted Canyon. This rock intruded diabase and older rocks, and shows chilled margins adjacent to the earlier volcanic rocks. The quartz monzonite displays spectacular hydrothermal-alteration effects.

A welded dacitic ash-flow sheet blankets the earlier volcanic rocks in the vicinity of Haunted Canyon, and caps the Kings Crown Peak-Apache Leap escarpment. Lamb (this paper) reports a welded dacitic ash that is presumably the same flow cropping out southwest of the Superior area, in south-flowing tributaries to Walnut Canyon.

The dacite was erupted as a series of ash flows that followed each other rapidly enough for the sheet to form a single cooling unit, which in this area is 500 to 2000 feet thick (Peterson, 1961). Peterson (1961, p. 66-71) believes that a possible source for some of the ash flows, and presumably for the earlier volcanic rocks, is an oval-shaped area approximately 4 miles long by 3 miles wide in the southwest part of the Haunted Canyon quadrangle, that may contain the roots of a caldera.

TERTIARY ROCKS SOUTH AND WEST OF SUPERIOR, ARIZONA

By D. C. Lamb

In contrast to the region east of the Kings Crown Peak-Apache Leap escarpment, field evidence indicates that other volcanic activity in the area south and west of Superior post dates the emplacement of the Apache Leap welded dacitic tuff flow. That the tuff flow extended farther west beyond the Concentrator fault may be seen in numerous disjointed fault blocks in the vicinity of Hell's Peak on Walnut Wash, and in several fault blocks extending eastward from Woods Creek to the main zone of the Concentrator fault.

In no single locality is the complete volcanic sequence exposed. Following emplacement of the dacite, downfaulting of the Superior basin, and deposition of the "Gila Conglomerate", volcanic activity resumed with the emplacement of basaltic tuff and flows. This initial basaltic eruption was apparently closely followed by the creation of numerous rhyolitic volcanic vents, and the accumulation of hundreds of feet of coarse, bedded tuffaceous sediments, suggesting periods of violent eruption. At least two periods of eruption are evident, each being terminated by the eruption of viscous rhyolite. Of this later phase, the bulk of the material is an accumulation of glassy siliceous flows that locally reach a thickness of over 600 feet. Much of the glass is perlitic, especially in the vicinity of Picket Post Mountain; it currently is being utilized for light-weight plaster and concrete aggregate.

The culminating volcanic event in the area was upwelling of olivine basalts along fault zones in the Concentrator complex. In two localities, the basaltic eruption was terminated by the violent expulsion of bombs (some three feet across), cinders, and finally a siliceous ash. These may be seen along Highway 177 in the vicinity of the Smith Ranch.

Locally, the siliceous tuff deposits reach a thickness of nearly 1200 feet. The bedded aspect suggests violent convectional action during the eruption, causing reworking and disintegration of pumice fragments, and grading of the included rock fragments. Within the stratified zones, massive layers of unsorted ejecta with fresh, coarse fragments of pumice and rhyolite are common. The tuff piles stand topographically high, forming two broad synclinal plateaus. One is cut deeply by Martinez Wash along the border of an extensive intrusive rhyolite complex to the east, and is terminated abruptly by an erosional escarpment to the west and south where Precambrian granite and Pinal Schist are exposed. The second tuff plateau extends eastward and southward from Picket Post Mountain to the vicinity of Copper Butte. The complete eruptive history of the thick tuff sequences is as yet undeciphered, but locally individual zones can be traced to nearby rhyolitic vents that show both intrusive and conformable relationships with the tuff.

More than thirty simple and compound volcanic necks of rhyolitic composition have been mapped. Of these, Hell's Peak, at the confluence of Hell's Canyon and Walnut Canyon, is most conspicuous. The position of the vents appears to have been controlled by lines of structural weakness related both to Precambrian and Tertiary deformation. In the northern half of the region, a number of nearly circular vents are scattered with little apparent relationship to each other; whereas in the southern half of the region, compound vents and dike-like bodies of rhyolite are aligned in a massive complex from just south of Cochran on the Gila northward for nearly six miles.

Detailed mapping of one of these by Bohmer shows a complex sequence of events during emplacement. The neck was not punched through as a plug, but evolved in a series of stages including the formation of an intrusive tuff, suggestive of the process of fluidization described by Doris Reynolds and others. In nearly all cases, the necks are surrounded by a zone of glass.

Although all field evidence found to date suggests a single multi-phase eruptive sequence for the region, detailed petrographic examination must be completed before this can be stated conclusively. The region is complicated by numerous faults and other structures not yet completely understood. The possibility of an earlier eruptive sequence prior to the eruption of the Apache Leap dacite, as in the area to the east, cannot be conclusively ruled out until this study has been completed.

STRUCTURE

General Statement

The dominant structural features in the Superior area have a direct reflection in topography. Relative downward movement of a structural block west of the Concentrator fault has formed the Superior basin, and exposed the thick sequence of sedimentary rocks and dacite along Apache Leap. South of the Conley Spring fault, between the Concentrator fault and the dacitic capping, the layered rocks are tilted eastward and rent by a complex of major faults which are subsidiary to the Concentrator fault. West of the Concentrator fault, the down-dropped Superior basin is filled with horizontal to eastward-dipping volcanic flows, tuffaceous sediments, and alluvium, and is cut by north-south and northeast-striking faults. North of the Concentrator and Conley Spring faults, the rocks are tilted eastward and cut by east-west and northwest-striking faults, but are not highly deformed. In the vicinity of Peterson's proposed caldera, the pre-volcanic rocks are jumbled, and show an intricate, heterogeneous fracture pattern.

Folding

Sedimentary rocks of the Kings Crown Peak-Apache Leap escarpment are warped into a broad eastward-plunging syncline. With this exception, major fold structures in the Superior area are few but spectacular. The "Elm overthrust," in Naco Limestone beneath the dacite at the head of Elm Canyon, has the form of a large recumbent fold. The origin of this structure has yet to be determined. South of Picket Post Mountain, beds of the Apache Group are displayed in a vertical to steeply eastward-dipping attitude. On the west side, Pinal Schist crops out at elevations higher than the sedimentary beds; but toward the east (Superior basin), these beds are buried beneath the later volcanic flows. Here, relations suggest that these beds represent the beveled, upturned edge of a monoclinal fold.

Faulting

East-trending faults in the Superior area are generally mineralized with manganese and iron oxides. The Magma fault (vein) is the most important of these, but minor east-west breaks from Magma Chief ridge to south of the Belmont Mine also are mineralized. Some were intruded by thin dikes of diorite porphyry. Three miles south of Superior, Peterson (oral communication) mapped an east-trending diabase dike that intruded Troy Quartzite, but is overlain by rocks of Cambrian age. This relationship suggests that at least some of the east-west faulting is Precambrian in age.

Northwest- and northeast-trending faults occur throughout the area, but with few exceptions show minor displacement. Within the Magma Mine, these faults cut the Magma vein and exercise a distinct control on the shape and placement of ore bodies, attesting to the pre-mineral age of the faulting.

The Concentrator fault trends northward throughout most of the area discussed here, but at Superior it bends abruptly northwestward, generating a broad zone of ruptured rock within the bend. Near the north side of this deflection, the Conley Spring fault branches away to the southeast, and can be traced more than four miles, into the dacite. Mapping by J. K. Gustafson (1945, unpublished report to Magma Copper Company) showed the Main fault to be a sigmoidal split of the Concentrator fault, and that there is a sizeable left-lateral component in the movement along the Concentrator zone. No reliable estimate is available for the horizontal or vertical movement along the Concentrator fault, but we may surmise that the displacement was of the order of thousands of feet. The effects of late vertical (tensional(?)) movement along the Concentrator fault zone are apparent in the topographic expression of the Superior basin, and in the Magma Mine where north-striking faults gape open, commonly forming water courses that are filled by aragonite and calcite.

Some of these same faults have controlled mineral deposition and are pyritized away from the main vein. The suggestion here is that, although much of the movement is relatively late (post-dacite), the Concentrator fault and its subsidiary structures had their origin prior to mineralization in the Superior area.

Tilting

The uniform eastward dip of sedimentary rocks along the Kings Crown Peak-Apache Leap escarpment, and the eastward dip of layering in the dacite overlying these rocks, are among the striking features of the Superior area. Short (1943, p. 96) suggested that mineralization and oxidation of the Magma deposit occurred after tilting of the sedimentary beds, and before eruption of the dacite. More recent studies of mineralization trends in the Magma Mine suggest the same conclusion.

The east-dipping layering in the dacite along the escarpment could possibly be interpreted as indicating post-dacite tilting. However the sedimentary beds along the escarpment maintain a uniform 30- to 45-degree eastward dip, whereas layering in the overlying dacite dips only 15 to 25 degrees eastward. Farther east, dips are variable; some are eastward and some are westward (Peterson, 1961, pl. 4).

Layering in the lower part of the dacite may reflect the attitude of the surface on which it was deposited (Peterson, oral communication). At least some of the dacite dips may be interpreted as being primary features, with the dacite deposited on dip slopes of the older rocks.

If at least part of the tilting in the Superior area occurred prior to mineralization, and if mineralization was "Larimide" (associated with Mesozoic(?) intrusive bodies), then at least part of the tilting would have taken place prior to or during Early Tertiary time.

SUMMARY OF MESOZOIC AND TERTIARY EVENTS

During Mesozoic or Early Tertiary time, the Superior area was tilted eastward. This deformation may have been in part contemporaneous with the emplacement of a quartz diorite stock near Silver King, and the intrusion of diorite porphyry plugs and dikes now exposed along the Kings Crown Peak-Apache Leap escarpment. Economic mineralization within the area is associated with this period of intrusive activity.

Post-intrusion erosion produced a surface of considerable relief, upon which Whitetail Conglomerate accumulated in the lower areas. Rhyolitic lavas erupted through vents probably located near the headwaters of Haunted Canyon, and were in turn intruded by a mass of quartz monzonite porphyry. Tremendous quantities of dacitic ash were then erupted, probably from the same extrusive center, covering several-hundred square miles of surrounding terrain to depths as great as 2000 feet.

Following eruption of the dacitic ash sheet, and probably contemporaneous with the development of basin-and-range topography during Miocene time (Lance, 1960, p. 157), the crustal block west of the Concentrator fault began to subside, forming a basin. Rhyolite flows and tuff, originating from vents south of Picket Post Mountain, covered much of the lower parts of this basin and tuff spread onto adjacent areas. "Gila Conglomerate" accumulated in the basin also, contemporaneous with and subsequent to the rhyolitic tuff. Later, volcanism punched numerous vents through the rhyolite-tuff sequence, and rhyolitic, dacitic, and basaltic flows climaxed the long igneous history of the region.

MINERAL DEPOSITS

General Statement

Mineralization is widespread within the Superior area. Mineral deposits are of two ages. The oldest, and by far the most important, are the stockworks, veins, and bedded replacement deposits associated with Mesozoic(?) intrusive rocks. These deposits are of mesothermal intensity, and include the Magma, Silver King, Lake Superior and Arizona, Queen Creek, and Belmont ore bodies. Related also are numerous east-trending fractures which, in limestone, contain manganese-quartz mineralization, and have localized minor pods of mineralization within favorable stratigraphic horizons. Most important of these horizons favorable for mineral replacement is a zone about 20 feet above the base of the Martin Limestone that is persistently mineralized throughout the area. Also noteworthy is the depositional control of the red shale (paleosol), at the top of the Mississippian beds, that localized mineable pods of manganese minerals in the limestone beneath the shale along east-striking faults.

The younger deposits have been of comparatively slight economic importance. They include the Talley-Wall Mine, the Reymert Mine, and other properties southwest of Picket Post Mountain. These epithermal deposits are related spatially, and probably genetically, to eruptive centers of the later volcanic rocks.

Magma Mine

The Magma Mine is the only property operating at present, and has accounted for the bulk of the production from the area. The Magma (formerly the Silver Queen) prospect was discovered in 1875, and worked intermittently until 1910. In 1910 the property was acquired by George Gunn and William Boyce Thompson, who organized the Magma Copper Company and initiated a mining enterprise that has operated continuously to the present time.

Copper minerals have replaced crushed fault filling and wallrock in the east-trending Magma fault and subparallel splits and branch faults, and replaced parts of a favorable bed of Devonian limestone. The Koerner vein, a sub-parallel structure 1100 feet south of the Magma vein, has also yielded a substantial tonnage of copper ore.

The Magma fault cuts all of the pre-Tertiary sedimentary rocks, diabase, and Pinal Schist. Parts of the fault are occupied by pre-ore diorite porphyry(?) dikes. Within the vein, ore-grade mineralization may occur adjacent to any of the pre-Tertiary rocks. Structure, rather than the chemical characteristics of the wallrock (with the exception of the Devonian replacement horizon), appears to have been the effective ore control.

The largest production has come from ore bodies which in gross outline plunge westward, parallel to the west-dipping Main fault (see vertical projection, in pocket). These are known as the Main ore body. The Main ore body has been followed from the surface to the 4900 level (levels are designated by distance in feet below the collar of No. 1 Shaft).

Eastward from the Main ore body, the structure of the Magma vein increases in complexity, sigmoidal vein splits become more numerous, and the oreshoots become more discontinuous. These oreshoots are known collectively as the Central ore zone (East ore bodies of Short). Above the 2550 level, zinc exceeds copper in the ore. Below this level, copper is the predominant metal. Between the

3400 and 3600 levels, finger-like blind ore shoots extend downward and coalesce into a semi-continuous zone of copper orebodies. Mining in the Central ore zone has extended to the 4000 level.

At the eastern extremity of the Magma vein system, a horizon 15 to 20 feet above the base of the Devonian Martin Limestone has been extensively replaced by copper and iron minerals adjacent to the South Branch vein, a split of the Magma vein. The sedimentary beds here dip about 30 degrees eastward, and economic mineralization extends from near the 2000 level down the dip to an unknown distance below the 3600 level. Laterally, the replaced beds extend as much as 1000 feet along the strike. In thickness, the replaced beds vary from 0 to 80 feet but probably average less than 25 feet.

Throughout both the vein and the limestone replacement deposits, the bulk of the quartz and pyrite were emplaced prior to copper-zinc mineralization, and pyrite was generally highly replaced by copper sulphides. Chalcopyrite is the most prevalent copper sulphide and has yielded most of the copper. Sphalerite, bornite (for which the mine is famous), chalcocite, tennantite, enargite, and digenite are present in notable quantities, and a host of copper minerals occur in minor quantities.

The main ore body exhibits distinct hypogene mineral zoning. In general, ores of the upper levels are oxidized, and supergene chalcocite is superimposed upon hypogene sphalerite-chalcopyrite-chalcocite-bornite ores. In the intermediate levels, chalcopyrite and bornite predominate; tennantite and chalcocite are subordinate. In the lower levels, chalcopyrite, enargite, and bornite predominate, but coexist with substantial amounts of chalcocite, tennantite, and digenite. All zoning changes are gradational.

Mineralization in the Central ore zone is somewhat different. Sphalerite predominates over chalcopyrite above the 2550 level. Below the 2550 level, ores tend to be pyritic, and chalcopyrite is the predominant copper mineral. It is only in the tops of blind oreshoots, and within the presumed main channelways of ore solution flow, that tennantite and bornite are found. Fringes and tops of ore shoots tend to be enriched in precious metals.

East replacement ores are paragenetically similar to ores from the Magma vein, although they vary considerably in appearance. Within the upper levels of the replacement ore body, the gangue is predominantly bladed specular hematite. Chalcopyrite is the chief ore mineral, but bornite, chalcocite, and tennantite are common. Quartz is rare, and pyrite only locally abundant. Below the 3000 level, pyrite becomes more prevalent in the ores, and hematite becomes relatively less abundant. Chalcopyrite provides an increasing percentage of the copper values.

Silver King Mine

The ore body at the Silver King Mine, 1 ½ miles north of Superior, is the only stockwork known within the area. Ransome (1912, p. 156) reports:

> The ore body formerly cropped out at the top of a little hill about 75 feet high, composed of much-altered yellowish-brown to greenish-gray (diorite) porphyry. . . . so far as can be seen from the surface, the ore body was not part of a vein and there is nothing to suggest that it was determined by the intersection of two or more persistent fissures. It apparently was a compact plexus of veinlets inclosed in comparatively unfissured porphyry. . . . the ore body was a stockwork about 130 feet in maximum diameter, with a general dip of 70° west.

Blake (1883) described the ore body as:

> . . . porphyry, so called, penetrated and seamed with interlacing veinlets of quartz, reticulating and crossing in every direction. These veinlets varied from the thickness of a sheet of paper to ¼ inch or an inch in thickness, and were generally accompanied with ore in a medial position, having quartz on each side of it next to the rock. . . . In addition to these veinlets there are masses and bunches of ore and apparently a central mass of quartz, a large and compact body, toward which the system of veinlets converged, or from which they may be said to radiate.

Short (1943, p. 146) discusses the Silver King ore as follows:

> Although the Silver King Mine was worked exclusively for silver, the most abundant minerals are those of lead, copper and zinc. The most important of the (hypogene) base metal minerals are sphalerite, chalcopyrite, tetrahedrite, galena and bornite. Much of the tetrahedrite contains a small amount of silver, but with this exception (supergene) stromeyerite and native silver were the valuable constituents of the ore.

The Silver King deposit was discovered in 1875 and operated profitably until 1887 when economic mineralization was bottomed on the 800 foot level. Exploration and intermittent operations were conducted until 1896, and again from 1916 until 1920.

Lake Superior and Arizona Mine, and Queen Creek Mine

In both of these properties, oxidized copper, gold, and silver ores have been mined from the contact between Cambrian quartzite and Devonian limestone, and from the Devonian replacement horizon 20 feet above the contact. Ore shoots are controlled by the intersection of steep east-trending mineralized faults with the replaceable horizon, and are eastward plunging "mantos" that follow the mineralized structure down the dip of the beds.

Belmont Mine

At the Belmont Mine, most of the development work was done on the Eureka vein, a strong, northeast-striking, mineralized fault. Despite intensive prospecting, very little ore was found. Mining by lessees of oxidized gold-silver ores from pods of replacement at the top of the Mississippian limestone has accounted for some of the production.

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