Geology of the Fortuna Mine, Yuma County, Arizona

by

Stephen M. Richard, Charles Ferguson, Steven Skotnicki

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Arizona Geological Survey
416 W. Congress, Suite #100, Tucson, Arizona 85701

INTRODUCTION

Location

The Fortuna mine is located on the western side of the central Gila Mountains in southwesternmost Arizona (Figure 1), just east of the western fork of the Camino del Diablo. The mine is located on a group of patented claims now within the Barry M. Goldwater Gunnery Range, which is owned by the U. S. Bureau of Land Management, but administered by the U. S. Marine Corps. Access to the mine requires obtaining a permit at the headquarters of the Gunnery range in Yuma.

History

The Fortuna deposit was discovered in late 1894 by Charles W. Thomas, William H. Halbert, Peter Farrell and Laurence Albert (or Albert Laurent) [Baker, 1980]. In 1896 the property was sold to Charles D. Lane, who organized the La Fortuna Gold Mining and Milling Company. Lane was a major stockholder in the Harquahala (or Bonanza) Mine, near Salome, Arizona, which was running out of ore at the time. Most of the mining crew from the Harquahala was transferred to the new mine at Fortuna [Buse, 1968]. The company built a mill at the mine site and laid a 4 inch pipeline more than 12 miles from a well on the Gila River flood plain near Blaisdell to supply water [Blake, 1898]. Prof. William P. Blake visited the mine in 1897 and his report, transcribed from a lecture to students at the 'School of Mines' (University of Arizona?), was included in the <u>Report of the Territorial Governor to the Secretary of Interior for 1898</u>. The original production shaft was located on a low hill (referred to here as Mill Hill) about 250 feet southwest of the main vein outcrop and was inclined 60° to N034E (all bearings reported measured in degrees clockwise from north) [Wilson, 1933]. Blake [1898] reports that this shaft was sunk normal to the plane of the mineralized zone, intersecting it at about 400 foot level (below surface). A second shaft, probably started in 1897 [unpublished Arizona Geological Survey files], was located about 100 feet southeast of the vein outcrop. This shaft was inclined 58° to N144E, and was more than 1000 feet deep [Wilson, 1933; unpublished Arizona Geological Survey files]. The Fortuna mine was active until 1904, producing 123,030 ounces of gold (3.8 metric tonnes). Underground recovery of pillars in the mine 1913-14 by Burt Enderton, and exploration in 1926 by the Elan Mining company brought the total production to 124,239 ounces of gold (3.9 metric tonnes) for the period 1896-1926 [Buse, 1968a;Wilson, 1933]. C. F. Tolman of Stanford University studied the geology of the mine area sometime around 1930 and proposed a location for the lost continuation of the vein system [Tolman and others, 1931?]. Some further production resulted from reworking of the tailings in about 1936 [Buse, 68b; clippings in files at the Arizona Geological Survey], development of two shafts on a 'newly discovered vein' by a crew led by William B. Maitland in 1939, and further underground work at 'the old shaft' of the Fortuna mine in 1941-42, also by W. B. Maitland [clippings in files at the Arizona Geological Survey]. No further mining activity has been reported. In 1966, 7 of the 8 patented claims at the mine were sold for $100.00 each to Guido E. Cagliere Jr. of San Francisco, California, whose father owned the remaining claim [anonymous, 1966]. The owners formed ZA, Inc., a Nevada corporation, and transferred ownership to the corporation. The patented claims are named Fortuna, Christmas Gift, Halfmoon, Arizona, Oregon, Alta, New Years (Figure 2), Alice, Famous XX, Baily XX and Washington, totaling about 234 acres[Buse, 1968a].

GEOLOGIC SETTING

The geology of the Gila Mountains has not been studied in detail. The only comprehensive description is from Wilson [1933]. The range is underlain by a sequence of south dipping gneisses intruded by a variety of foliated to massive granitoid. Wilson's [1933] gneiss unit includes quartzo-feldspathic gneiss that is apparently mostly meta-igneous rocks [Tolman and others, 1931?]. The schist unit of Wilson [Wilson, 1933] includes a variety of more biotite-rich, generally gneissic rocks, some of which are of metasedimentary or metavolcanic origin. Leucocratic, commonly muscovite-bearing, medium-grained granite plutons of probable Jurassic or Cretaceous age intrude the metamorphic rocks in the northern and central part of the range. The southern part of the Gila Mountains is underlain by granitoid of the Gunnery Range batholith. Wilson [1933] described the granite as typically rather coarse-grained, leucocratic with some darker gray phases, and consisting of quartz, feldspar (mostly K-feldspar), biotite and hornblende. Secondary epidote is common. Tolman and others [1931?] report that "numerous dikes and sills of porphyritic rock of a composition between that of diorite and diabase, and extremely basic sills" intrude gneisses in the vicinity of the Fortuna mine.

GEOLOGY OF THE MINE AREA

Rocks

Dark gray amphibolite gneiss and a lighter gray biotite-hornblende gneiss can be differentiated in the area of the Fortuna mine. (See map unit descriptions, p.7). The protolith of the amphibolite gneiss was probably a mafic volcanic sequence, as suggested by the bulk composition of the rocks, the compositional heterogeneity, and the presence of small amounts of marble. The protolith of the amphibole-biotite gneiss was probably compositionally immature, relatively massive calcareous sandstone, as suggested by the generally slight variation in composition from layer to layer, the relatively low quartz content, abundance of epidote, and lack of meta-conglomerate or pelitic units. The contact between these two units on the NE side of the canyon SW of the main shaft is interleaved, probably by tight isoclinal folding during the development of the strong foliation in these rocks. Tolman and others [1931] describe a series of units in the gneiss distinguished by variations in the amount of hornblende and garnet present and the thickness of layering (which they referred to as bedding). Subtle compositional variations may define more detailed mappable units, but we were unable to recognized these during our reconnaissance. The strong deformation and probable lateral variability of the protolith will make definition of stratigraphy in these gneisses tenuous at best.

The apparent coexistence of garnet and hornblende in some units within the amphibolite gneiss package suggests at least amphibolite facies conditions. Wilson [1933, p. 192-193] reports that plagioclase in samples from near the original outcrop of the Fortuna vein is andesine or labradorite, and that gneiss immediately adjacent to the vein contained hornblende, pyroxene, andalusite, epidote, biotite, quartz and calcite. No evidence of partial melting was observed. The presence of large retrograded porphyroblasts in the hornblende-biotite gneiss (see descriptions below) and sieve textures in hornblende defining the mineral lineation observed in some foliation surfaces suggests that a static recrystallization event may be superimposed on the metamorphism associated with development of the gneissic foliation.

The age of the protolith and the timing of metamorphism and deformation in these gneisses is only constrained to pre-date the Gunnery Range batholith of probable Paleocene age [R. M. Tosdal, personal communication, 1996]. Eberly and Stanley [Eberly and Stanley, 1978] reported biotite K-Ar dates of 203 ± 9 and 326 ± 16 Ma from gneiss in the northern Gila Mountains, and suggested a Precambrian protolith with Jurassic recrystallization. Similar gneissic rocks in the Cargo Muchacho Mountains are interpreted to record an episode of Jurassic plutonism, contraction, and metamorphism [Tosdal and

Boettcher, 1994]. More geochronologic data are necessary to unravel the history of gneisses in the Gila Mountains.

Gneisses in the area of the mine are intruded by NE- to N- trending pegmatite dikes. The dikes are generally 0.3 to 1 m thick, but locally form elongate, slightly discordant pods, up to 10 m thick and 50 m long. The pegmatites mostly consist of feldspar and quartz with accessory muscovite and garnet and sparse tourmaline. One dike has abundant large biotite flakes (up to about 10 cm in diameter) with only minor muscovite and garnet. Exposed contacts of pegmatite dikes were brittle crush zones. Smith and Graubard [Smith and Graubard, 1987] report that pegmatite dikes are intimately associated with gold-bearing quartz veins. We did not observe this relationship in our reconnaissance. The pegmatites are interpreted to be related to the Gunnery Range batholith, based on their similar peraluminous mineralogy [Smith and Graubard, 1987].

Structure

Gneissic fabric

Strong deformation of gneissic rocks in the Fortuna mine area at probable amphibolite-facies metamorphic conditions has produced a penetrative, relatively planar gneissic fabric in all rocks. This fabric strikes ENE to NE, dips SE, and contains a mineral lineation defined by aligned hornblende porphyroblasts on many foliation surfaces. Strong deformation is suggested by the presence of tight to isoclinal folds along lithologic boundaries. The prominent layering in the rocks almost certainly represents a compositional layering transposed from an older layering, which may have been sedimentary bedding or possibly an older metamorphic fabric.

Brittle faults

Tolman and others [1931?] describe the geometry and outcrop of faults they mapped in some detail. Unfortunately, we did not have access to their map and had to interpret the location of the faults they discuss based on our surface observations. Fault names, slips and separations reported in this discussion are based on our mapping, and interpretation of the geology as described by Tolman and others[1931?].

The major faults in the area trend northwest, dip northeast, and control the topography of the mine area. The major fault of this set is the Queen fault, interpreted to have a right slip component of 535-550 feet and a normal component of 150 to 300 feet, based on matching pegmatite dikes and 'stratigraphy' in the gneiss across the fault. The Queen fault zone is exposed in road cuts along the SW side of the southeast end of the Mill Hill ridge as a zone of shattered gneiss in which the foliation has been dragged to a NW-SE strike and NE dip. Tolman and others[1931?] interpreted that the northwest-trending faults cut a set of north-trending, east-dipping faults. One fault of this set is exposed in a prospect shaft 1200 feet NE of Mill Hill, trending N010E, dipping 90°. About 0.7 m of gouge derived from gneiss and pegmatite was observed in the fault zone. The gouge is strongly iron stained and contains some secondary copper minerals. A second fault of the north-trending set cuts pegmatite dikes and a contact between the amphibolite and hornblende-biotite gneiss units about 800 feet east of this fault. No exposures of this fault were observed. The north-trending fault exposed in the prospect pit is interpreted as a northward continuation of the Archduke fault, offset to the SE by NW-trending faults. At the Archduke fault between the 5 and 6 levels in the Fortuna mine the ore zone is displaced 260 feet down in the hanging (eastern) wall. Several of the NE-trending pegmatite dikes are sheared along their contact, indicating some displacement parallel to the dikes.

Numerous other planar zones of gouge and breccia were observed in the prospect pits in the vicinity of the mine, but could not be followed outside of the excavated exposures. One such zone is visible in the collar of the main shaft, oriented approximately N140E dipping 60°NE. Float of similar appearing breccia in the mine dump contains numerous silica veinlets, and biotite and hornblende in the clasts and gougy matrix are chloritized.

MINERALIZATION

Prior to development, the main vein at the Fortuna mine cropped out at the north end of the 'Mill Hill'. A fault trending N040E and dipping 55 to 70° SE crops out in the caved glory hole where the vein was mined [Wilson, 1933; Figure 3]. The ore zone was chimney-like, elongate down the plunge, but less than about 20 feet thick, and no more than 500 feet long along the strike. The strike changed with depth. The vein cropped out in two branches a few feet apart at the surface, which joined at a depth of about 500 feet.

According to Blake [1898], the vein was concordant with gneissic foliation at the surface, but was slightly discordant deeper in the mine. Where the vein cropped out it contained some green copper staining and some 'yellow colors'. Gold occurred as free gold, and very little sulfide was reported. Bullion from the upper part of the vein contains more copper than that from lower levels. This may be because less of the copper ore from deeper levels was oxidized and was not recovered by the amalgamation process used in the mill [Blake, 1898].

Tolman and others [1931] give a detailed description of the ore body as follows:

> "The ore shoot occurs as a lenticular replacement... and outcrops west of the main Fortuna shaft in two lenses, the "west shoot" and "east shoot." These two pipes were followed down separately and retained their entity until the 5 level where they joined, though one section 150 feet in length was too small and lean to mine. On the 2 level and probably to the 4 level, the eastern edge of the ore body is cut and displaced by the Count fault. From the 4 level to slightly below the 8 level the ore is continuous, reaching a maximum length of 500 feet below the 5 level. Slightly below the 5 level the western edge of the ore body rakes into and is cut off by the Queen fault. Between the 5 and 6 levels the eastern edge of the ore body is cut by the Archduke fault and is displaced approximately 260 feet on this fault, and is picked up again on the 9 level. That portion of the ore remaining on the footwall of the Archduke is rapidly cut off by the north-dipping Queen fault until it is completely truncated at a point approximately 70 feet below the 8 level. The portion on the hanging wall of the Archduke fault was mined to the 11 level where, again, due to its rake, it is cut and displaced by the Queen fault. The ore is a continuous body from the surface until it is cut off by the Queen fault. It has an average width of approximately 3.5 feet and a maximum length along the strike of almost 500 feet. The ore body dips with the schistosity and rakes slightly more easterly than the dip. The quartz runs from nil to, reputedly, $40.00 to $50.00 a ton. The vein is reported to be widest and richest at the point of cut off."

The ore consisted of massive, granular, vitreous quartz, normally slightly yellowish to tan colored, and with minor green copper stain. The gold occurred as free gold with no accessory minerals. In thin section no evidence of strain phenomena in the anhedral quartz crystals was observed [Tolman and others, 1931?]. Tiny grains and veinlets of hematite, partially altered to limonite were present between the quartz grains, and trace amounts garnet, magnetite and feldspar have been reported from the main vein system. The gold occurred as "round grains within converging hair-like cracks and also as thin, irregular veinlets within the limonite" [Wilson, 1933]. Smith and Graubard [1987] report that in samples they analyzed, base metal content was extremely low, with relatively high Cu/(Cu + Pb + Zn) ratios, and that arsenic and antimony were quite low.

Wall rock alteration associated with the vein was mainly silicification and carbonatization [Wilson, 1933]. During our reconnaissance, alteration observed adjacent to the quartz veins exposed in shafts and prospects NE of Mill Hill is very localized along the veins with selvages only a few cm thick. Virtually all of the rock on the mine dump NE of Mill Hill is megascopically unaltered.

In several prospects southeast of the main shaft, synmetamorphic quartz veins contain minor amounts of pyrite. The veins consist of white bull quartz, with scattered lenses with variable assemblages of minerals, including brown calcite, garnet, hornblende, and sparse pyrite. The pyrite is typically altered to limonite, with some associated chloritization of adjacent biotite or hornblende (supergene?). The veins are concordant lenses, 5 to 25 cm thick.

A number of features indicate that mineralization probably occurred at high temperature. The lack of any banding in the quartz veins and the coarse, granular and vitreous nature of the quartz are quite unlike typical epithermal quartz veins. The lack of any significant retrograde alteration of the amphibolite gneiss (propylitization) associated with the veins suggests that ore forming fluids were nearly in equilibrium with the metamorphic assemblage in these rocks.

Smith and Graubard [1987] interpreted that the gold-quartz vein mineralization was deposited by residual fluids expelled during final crystallization and differentiation of the peraluminous calcic igneous rock similar to the Gunnery Range batholith. An alternative hypothesis is that the gold-quartz veins are syn-metamorphic, related to dewatering of the host gneisses during amphibolite-facies metamorphism of Precambrian, Jurassic, or Late Cretaceous age. The mafic host gneiss is a possible source for the gold. Some remobilization of the gold by fluids related to the Gunnery Range batholith would explain the observed association of veins and pegmatites described by Smith and Graubard [1987].

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MAP UNITS

Late Tertiary and Quaternary deposits

Qs Undivided surficial deposits. (**Quaternary**) Alluvium and talus, undifferentiated.

Qtc Talus and colluvium. (**Holocene and late Pleistocene**) Unconsolidated, poorly sorted, angular gravel to boulder-size sediment on steep slopes.

Qo Older alluvium. (**Middle to early Pleistocene**) Surfaces underlain by coarse gravel and cobbles to boulders, with minor amounts of finer-grained material. Commonly forms a 1-5 m thick veneer unconformably overlying older basin fill or bedrock. Surfaces are relatively deeply dissected, with ~7 to 10 m of relief above active channels. Remnants are comparatively small, and are found on well rounded ridges between entrenched channels. Pavement of the surfaces is not well preserved due to extensive erosion and/or clast weathering. Remnants are typically covered with abundant fragments of pedogenic carbonate, many of which are >5 mm thick, derived from brecciated laminar petrocalcic horizons and carbonate clast-coatings. The fragments and coated clasts commonly lend a lighter-colored appearance to these remnants.

Tertiary, Mesozoic or Proterozoic

diorite porphyry dike. Fine grained medium grained dike intrudes the amphibole biotite gneiss discordant to the gneissic foliation. Consists of plagioclase and biotite crystals up to about 3 mm in diameter in a very fine-grained gray groundmass. Only one such dike was observed.

Mesozoic

pegmatite dikes. White quartz-K feldspar-plagioclase pegmatites. Grain size ranges from 5 mm to 30 mm. Finer grained parts commonly have a graphic texture. Most of the pegmatites contain accessory garnet and muscovite, but a small percentage contains large (up to 20 cm long) biotite crystals and no garnet or muscovite. These are not distinguished on the map, as many of the dikes were mapped from a distance. No systematic pattern in the occurrence of the biotite pegmatites was observed.

Mesozoic or Proterozoic

KXag Amphibolite gneiss. Dark gray amphibole, biotite, plagioclase, quartz gneiss. Compositional layering 5-20 cm thick is defined by abrupt variations in the mafic to felsic mineral ratio. Layers commonly are lenticular, probably due to transposition of older compositional layering (bedding?). Amphibole is aligned in a lineation on some foliation surfaces, but apparently spray oriented on others. Aligned amphibole contains poikiloblastic inclusions of quartz and feldspar. Light-colored metamorphic segregations(?) consist mostly of quartz, tan carbonate (calcite?), with variable amounts of hornblende, garnet, tourmaline(?) and pyrite. Pyrite is mostly altered to limonite, with associated bleaching of surrounding mafic mineral phases. Unit is distinctly darker colored and more amphibole rich than the amphibole-biotite gneiss. Apparently derived by deformation and metamorphism of a mafic metavolcanic sequence.

KXbg Amphibole-biotite gneiss. Medium gray, biotite-hornblende-plagioclase-quartz-epidote gneiss. Compositional layering 5-20 cm thick defined by variation in mafic mineral content. Unit is generally lighter colored and more homogeneous than the amphibolite gneiss unit. Hornblende prisms are aligned to define a mineral lineation in some foliation surfaces, and are spray oriented in others. Some units contain garnet porphyroblasts up to about 4 mm in diameter. Prismatic porphyroblasts up to 8 cm long in the gneiss along the NE side of the canyon SE of the main shaft at the Fortuna mine have been completely retrograded to white mica and chlorite. Epidote occurs as disseminated, very fine anhedral grains that impart a slightly greenish color to fresh surfaces. This unit was probably derived by metamorphism of calcareous graywacke.

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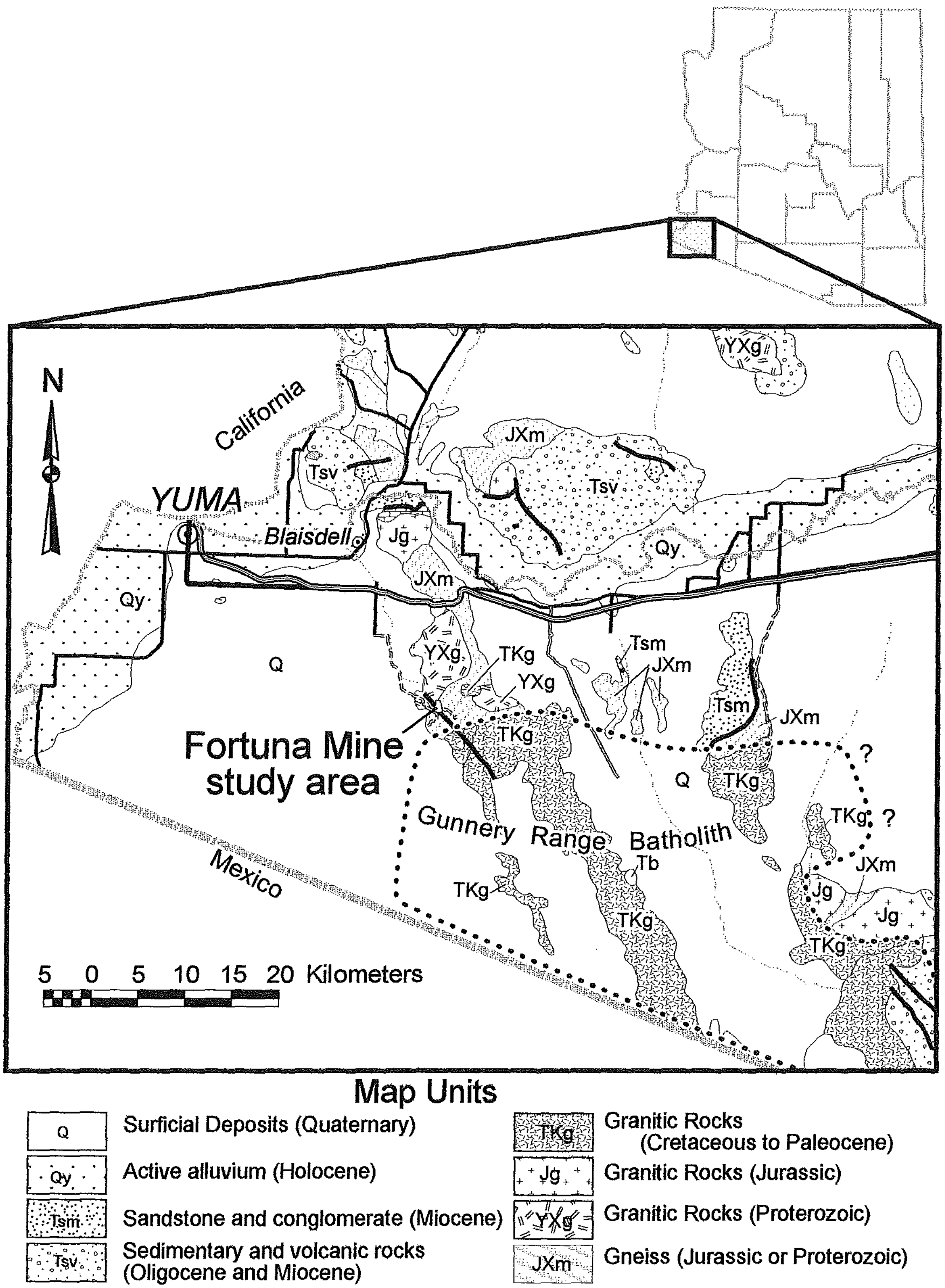

Figure 1. Regional geology and location of Fortuna Mine study area.

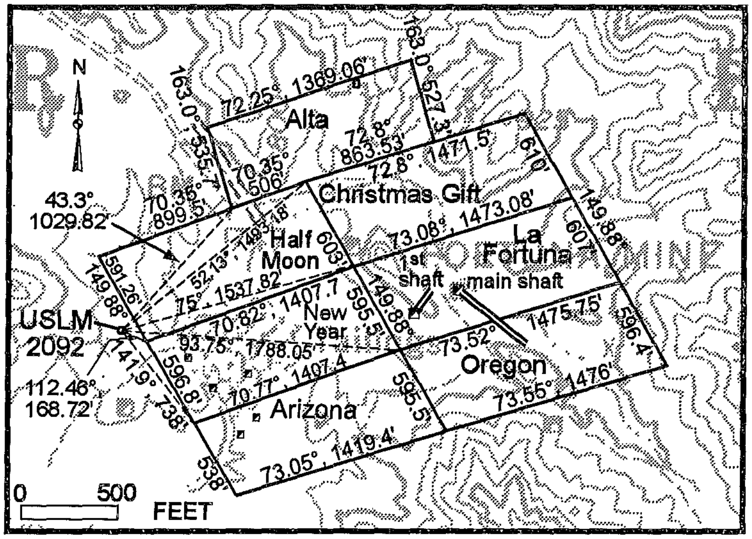

Figure 2. Claim map showing location of claims present in 1905, and map projection of major mine shafts. Surveyed by William H. Elliott, June 13-20, 1905. From files at the Arizona Dept. of Mines and Mineral Resources. All bearings in degrees east of north. Base map from Fortuna Mine 1:24000 scale topographic quadrangle. Survey is referenced to USLM No. 2092, which is not shown on the current topographic map.

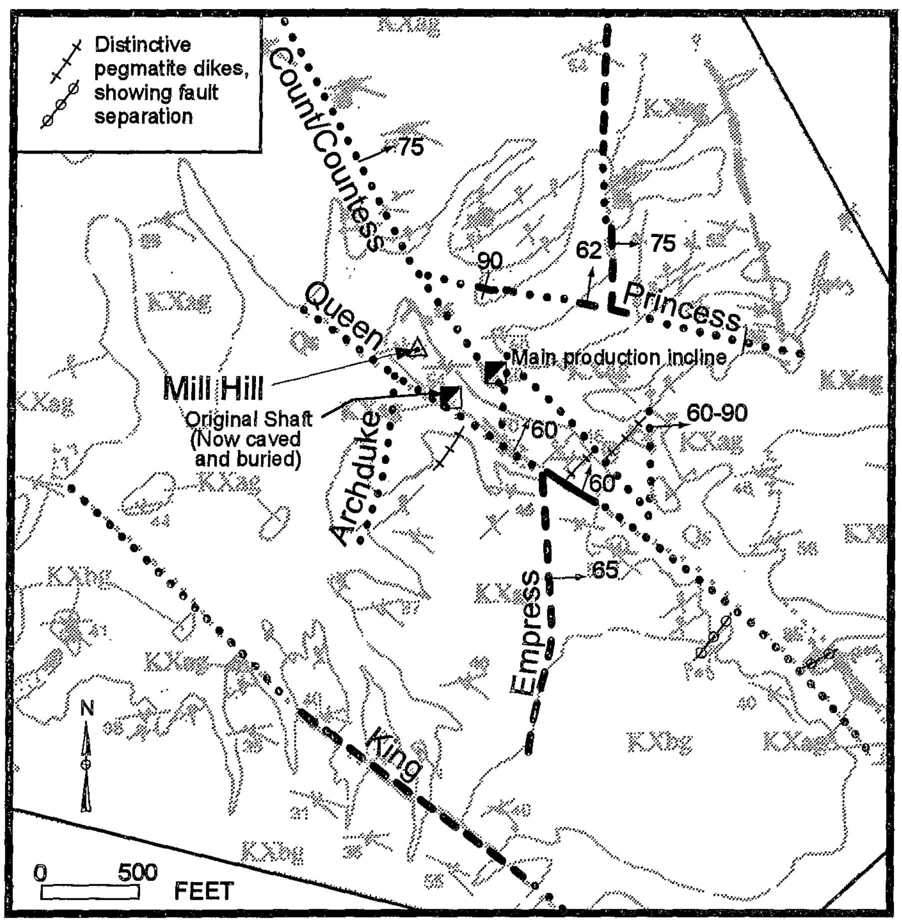

Figure 3. Map showing place and fault names inferred from Tolman et al.[1931]. Base map is Figure 4 from this report.

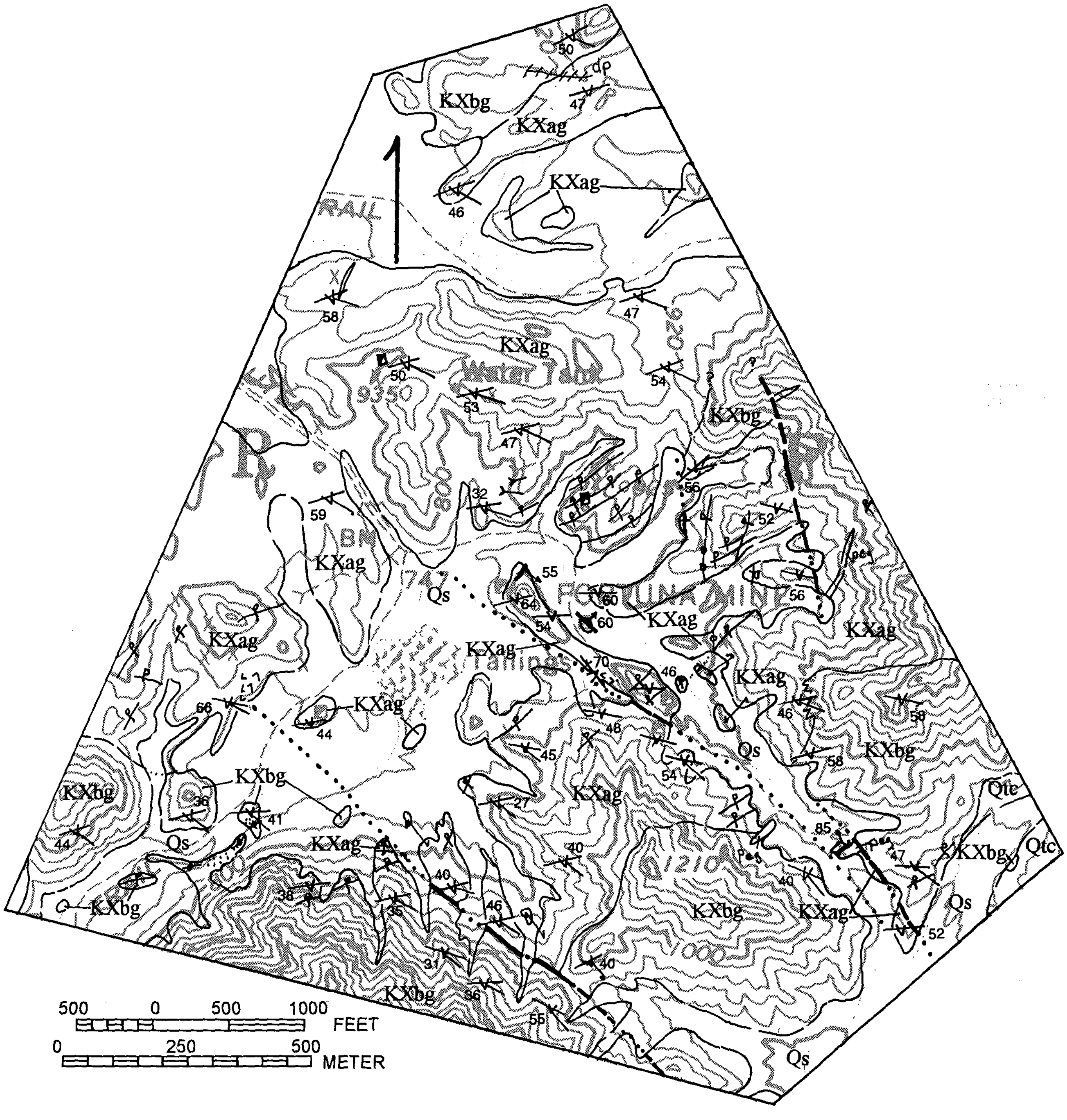

Figure 4. Geologic map of the Fortuna Mine area. Map Units are explained in the text (see page 8).

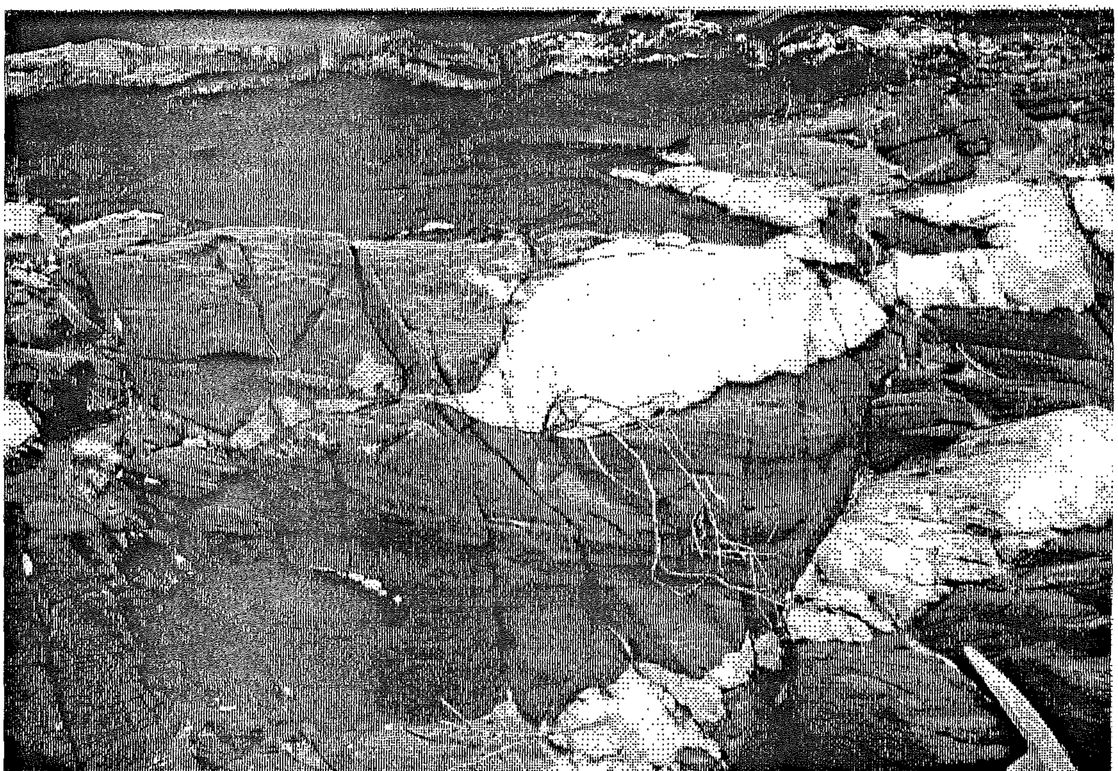

Figure 5a. Photograph of amphibolite gneiss in polished exposure in main wash about 1 km north of the Fortuna Mine. This lithology is the host rock for all mines in the area. Note two types of quartz veins: thin, concodant quartz-calcite veins (top of photo), and discontinuous, discordant, somewhat thicker veins. Mineralization is believed to be associated with the thicker, discordant veins.

Figure 5b. Slightly discordant quartz veins a the opening of an inclined shaft at the Christmas Gift property, directly north of the Fortuna Mine. View to the east.