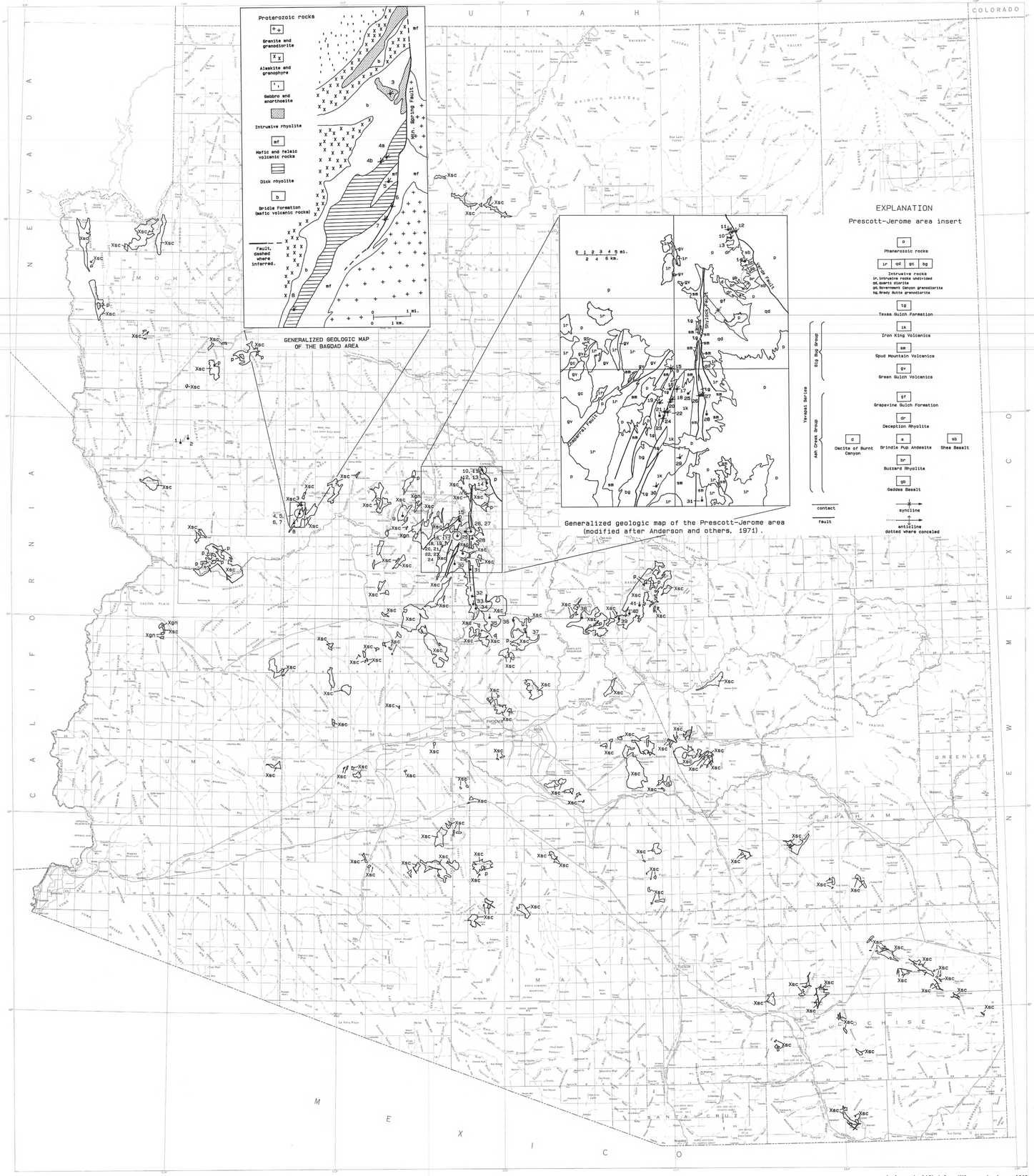
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1853-B
VOLCANOGENIC MASSIVE-SULFIDE MAP SERIES



Base from U.S. Geological Survey, 1974

Geology simplified from Wilson and others, 1969 and Anderson and others, 1971

SCALE 1:1 000 000

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METALLOGENIC MAP OF VOLCANOGENIC MASSIVE-SULFIDE OCCURRENCES IN ARIZONA

By

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VOLCANOGENIC MASSIVE-SULFIDE MAP SERIES

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1988

EDITOR'S NOTE

The metallogenic map of volcanogenic massive-sulfide occurrences in Arizona is one of several planned or published preliminary and interim products of a study of the distribution and setting of volcanogenic massive sulfides in the western United States. Volcanogenic massive-sulfide occurrences are inferred to be associated with the development of volcanic arcs or with rift systems in a mainly subaqueous environment. The massive-sulfide occurrences on this map were probably deposited in ancient island-arc environments. Most are considered to be proximal with respect to their emplacement near centers of volcanic activity. Some may have been deposited distal from volcanic centers.

The distribution of favorable host rocks for massive-sulfide deposits is also shown on the map. The host rocks are not necessarily formal stratigraphic units, and they may contain several lithologic types. They are shown here in order to delineate areas that may contain undiscovered massive-sulfide deposits.

SUMMARY OF PROTEROZOIC VOLCANOGENIC MASSIVE-SULFIDE OCCURRENCES IN ARIZONA

Volcanogenic massive-sulfide occurrences comprise a distinct 1.7-1.8-b.y.-old metallogenic province in Arizona. All of the 41 occurrences shown on this map are stratabound accumulations of iron and base-metal sulfides containing variable amounts of gold and silver. Lode deposits and occurrences of questionable origin have been omitted. A review of information on these deposits shows that they are widely distributed throughout the Early Proterozoic metavolcano-sedimentary succession, but they share many similarities (Donnelly and Hahn, 1981).

Regional geologic setting

The massive-sulfide occurrences are hosted in a thick succession of submarine volcanic and volcaniclastic rocks exposed intermittently from east-central Arizona to the northwestern part of the state. More than three-fourths of the deposits and prospects occur in 1,740-1,790-m.y.-old volcano-sedimentary strata of the Yavapai Series in western Arizona and the Prescott-Jerome area. This age range and other ages in this report are based on revised decay constants (Steiger and Jäger, 1977) and are approximately 30 m.y. younger than previously published ages.

Massive-sulfide prospects in the Tonto basin and the Mazatzal Mountains (localities 38, 39, 40, and 41) occur in metavolcano-sedimentary strata that are about 30-80 m.y. younger than the Yavapai Series (Silver, 1967; Conway and others, 1981). Recent fieldwork indicates that this volcanic succession extends westward into the New River Mountains and the Cave Creek area, and that it may unconformably overlie the Yavapai Series (Conway and Silver, 1984a,b). Massive-sulfide occurrences at localities 35, 36, and 37 appear to be hosted by this younger volcanic sequence, but stratigraphic relationships are uncertain (Conway, 1983). Alternatively, Anderson and Guilbert (1979) suggest that the Cave Creek-New River Mountains section is intermediate in age between the Yavapai Series and the Tonto Basin-Mazatzal Mountains strata.

Two or more periods of folding are recognized in the Yavapai Series, whereas only one major deformational event is evident in the younger volcanic strata. Throughout the metallogenic province, metamorphic grade is primarily greenschist facies with amphibolite facies developed locally. In most cases, primary textures permit identification and interpretation of protoliths.

Massive-sulfide deposits

Since the late 1800's, stratabound Cu-Zn-Pb sulfide deposits in Arizona have produced nearly 44 million tons of ore. Ten occurrences contained more than 100,000 tons of ore each, and three deposits yielded more than 4,000,000 tons each. The bulk of the production, however, was from the United Verde mine (locality 10), which produced more than 30 million tons of Cu-Au ore over a span of 68 years. Mine maps and cross sections of Anderson and Creasey (1958) suggest that the United Verde orebody contained more than 80 million tons of pyritic massive and semi-massive sulfides and stockwork ore.

The massive-sulfide deposits have many features in common, including mineral assemblages, hydrothermal alteration, and structural complexity. Regionally, they are tightly clustered, with 25 of the 41 occurrences confined to three districts. Within a district, deposits can occur in nearly all facies of the mafic to felsic volcanic piles and at numerous stratigraphic levels. Most of the occurrences are associated with felsic volcanic rocks, but several, including the 1.5-million-ton Old Dick/Bruce deposit (locality 4), were formed during the waning stages of mafic volcanism and clearly predate the overlying felsic eruptives.

The massive-sulfide deposits belong to the Cu-Zn group of volcanogenic deposits. Only one deposit, the Iron King mine (locality 15), contained appreciable amounts of lead. Published data on precious metal values are sparse, but by-product gold and silver were certainly economically important in many of the deposits. Sulfide assemblages are simple and consist primarily of pyrite, pyrrhotite, sphalerite, chalcopyrite, and galena. The sulfide ores exhibit primary mineralogical banding, and relict sedimentary textures can be found locally.

Chert and cherty sericitic tuffs occur along strike with or in close stratigraphic association with most of the sulfide bodies. Oxide-facies iron formation and ferruginous chert are reported from 17 occurrences.

All of the major deposits exhibit hydrothermally altered footwall zones that reflect varying degrees of chloritization, sericitization, and silicification. Alteration pipes are characterized by a chloritic core and a sericitic outer zone. Chloritic "stringer ore" or stockwork ore was economically important in several deposits, including the United Verde and the Old Dick/Bruce. Large semiconformable zones of silicification, epidotization, and albitization lie stratigraphically beneath the alteration pipe at the Old Dick/Bruce deposit (Conway and others, 1985) but have yet to be documented elsewhere.

The sulfide orebodies have high ratios of plunge length to strike length and were clearly deformed within the encasing volcanic strata. Many of the larger deposits are described as elliptical lenses or as rod-like bodies that plunge steeply and are parallel to major or minor fold axes. Ratios of plunge length to strike length are as much as 8:1 at the Blue Bell (locality 29), and stretching ratios of 3:1 are not uncommon elsewhere. Consequently, most deposits present small exploration targets at the surface.

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DESCRIPTION OF MAP UNITS FOR MAIN MAP

p — Cenozoic to Paleozoic rocks, undivided

Xsc — Schist, undivided (Early Proterozoic)--Metavolcano-sedimentary terrane 1.71-1.79 b.y. old that includes Vishnu Schist in the Grand Canyon area, Yavapai Series in central Arizona, Final Schist in southeastern Arizona, and unnamed schistose units

Xgn — Gneiss, undivided (Early Proterozoic)--Principally orthogneiss with some areas of undivided schist and granite

Contact

Fault--Dashed where approximately located

EXPLANATION OF SAMPLE LOCALITY SYMBOLS ON MAIN MAP AND INSET MAPS

39 — SAMPLE LOCALITY--Numbers are referred to in table 1

Copper

Gold

Lead

Silver

Zinc

4,5 — Cluster of sample locations

Table 1.--Proterozoic volcanogenic massive-sulfide occurrences in Arizona

[", approximate; ND, not determined; opt, ounces per ton]

Locality no.	Deposit name	Location	Age (b.y.)	Host rock lithology	Nature of exposure	Commodities	Remarks
1	Antler	34°52'57"N 113°58'06"W	1.7-1.8	Quartzofeldspathic schist--	Dormant underground mine.	Cu, Zn, Pb, Ag, Au	Produced 78,000 tons of ore grading 3% Cu, 6.5% Zn, 0.75% Pb, 1.1 opt Ag, and 0.01 opt Au.
2	Copper World	34°54'35"N 113°55'15"W	1.7-1.8	----------do.----------	--------do.--------	Cu, Zn, Ag, Au	Produced 61,000 tons of ore grading 3.5% Cu, 10.29% Zn, 0.66 opt Ag, and 0.0017 opt Au.
3	Copper King	34°34'11"N 113°13'45"W	~1.75	Felsic volcaniclastic rocks intercalated with basalts.	--------do.--------	Zn, Pb, Cu, Ag, Au	Produced about 23,000 tons of Cu-Pb-Zn ore.
4	Old Dick/Bruce	34°32'47"N 113°13'52"W	~1.75	At contact between thick basaltic unit and younger rhyolitic rocks.	--------do.--------	Zn, Cu, Pb, Ag, Au	Collectively, the Old Dick/Bruce ore bodies yielded 1,499,421 tons of ore grading 11.8% Zn and 3.5% Cu. The ore contained from 0.32 to 0.35 opt Ag, and from 0.0014 to 0.0026 opt Au.
5	Copper Queen	34°32'17"N 113°13'45"W	~1.75	Within rhyolitic tuffs and epiclastic rocks overlying an andesite unit.	Exhausted and closed underground mine.	Zn, Cu	Produced 140,350 tons of ore averaging 4.7% Cu and 14.4% Zn. The ore contained about 0.38 opt Ag and 0.0016 opt Au.
6	Rudkins	34°31'33"N 113°13'44"W	~1.75	Rhyolitic pyroclastic rocks--	Prospect with shallow shaft.	ND	No reported production.
7	Red Cloud	34°31'19"N 113°14'05"W	~1.75	Above a thin basaltic unit within rhyolitic pyroclastic rocks.	Prospect with shaft and adit.	Zn, Cu, Au, Ag	Produced about 200 tons of ore with an average grade of 6.4% Cu, 2.7% Zn, 0.69 opt Ag, and 0.075 opt Au.
8	Pinafore	34°29'27"N 113°16'39"W	~1.75	At contact between thick basaltic unit and younger rhyolitic rocks.	Prospect----------	Zn, Cu, Ag, Au	Produced about 1,900 tons with an average grade of 3.2% Cu, 13% Zn, 1.04 opt Ag, and 0.014 opt Au.
9	Boston Arizona	34°31'24"N 112°36'46"W	1.74-1.79	Volcanic wackes, and felsic volcaniclastics and tuffs.	Dormant underground mine.	Zn, Cu	Minor production.
10	United Verde (U.V.)	34°45'02" to 34°45'30"N 112°07'19" to 112°07'36"W	~1.79	Quartz crystal tuffs, fine-grained felsic tuffs, and associated felsic volcaniclastic rocks.	Dormant underground mine and open pit.	Cu, Zn, Au, Ag	World class deposit; produced total of 30,672,846 tons of ore averaging 4.77% Cu, 0.046 opt Au, and 1.65 opt Ag; 10 million tons of Zn-rich massive sulfide were left in ore body.
11	Haynes	34°45'23" to 34°45'23"N 112°07'48" to 112°07'53"W	~1.79	Crystal tuffs and fine-grained felsic tuffs.	Dormant underground mine.	Cu, Zn, Au, Ag	Blind ore body at a depth of >2,500 ft; developed from United Verde workings.
12	United Verde Extension (U.V.X.)	34°45'04" to 34°45'10"N 112°06'38" to 112°06'50"W	~1.79	Massive rhyolite, pyroclastics, and associated tuffaceous sediments with minor amounts of andesite lavas.	Dormant underground mine.	Cu, Au, Ag	Blind ore body; produced 3,878,825 tons of ore grading 10.23% Cu, 0.039 opt Au, and 1.71 opt Ag.
13	Verde Central	34°44'23"N 112°07'16"W	~1.79	Massive rhyolite and pyroclastics.	Dormant underground mine.	Cu	Occurs 4,000 ft south of U.V. mine. The deposit has ore reserves of 121,124 tons grading 2.94% Cu.
14	Copper Chief	34°42'00"N 112°05'23"W	~1.79	Basalt flows and tuffs--------	--------do.----------	Cu, Au, Ag	Also known as Equator-Iron King mine; produced about 400,000 tons of ore that averaged 0.4% Cu, 2.72 opt Ag, and 0.13 opt Au.
15	Iron King	34°29'38"N 112°15'45"W to 34°30'20"N 112°15'19"W	~1.75	Andesitic tuffaceous and volcaniclastic rocks interacalated with felsic tuff.	--------do.----------	Cu, Pb, Zn, Au, Ag	Mined to a vertical depth of 2,600 ft, the Iron King produced more than 5,659,749 tons of ore. More than 5 million tons contained an average grade of 2.50% Pb, 7.34% Zn, 0.19% Cu, 0.123 opt Au, and 3.69 opt Ag.
16	Victor-Swindler and Huron-Montezuma	34°27'12"N 112°15'38"W to 34°28'25"N 112°15'32"W	~1.75	Quartz crystal tuffs and tuffaceous metasediments.	Prospects----------	Cu, Ag, Au	No recorded production.
17	Lone Pine	34°27'57"N 112°14'57"W	~1.75	Rhyolite tuff, tuff breccia, and phyllitic metasediments.	Small, dormant underground mine.	Cu, Pb, Zn, Au, Ag	Incomplete records show that 2,763 tons of ore were shipped with average grade of 5.35% Cu, 0.20 opt Au, and 3.16 opt Ag.
18	Bogge	34°26'50"N 112°15'14"W	~1.75	Rhyolite crystal tuffs--------	--------do.----------	Cu, Zn, Au, Ag	Is about 5,900 ft south of the Lone Pine deposit. From 1943 to 1945, 98 tons of ore were shipped grading 1.07% Cu, 4.3% Zn, 0.45 opt Au, and 1.0 opt Ag.
19	Butternut	34°26'35"N 112°17'00"W	~1.75	Fine-grained felsic tuffs and tuffaceous metasediments.	Prospect----------	Au, Ag, Cu, Zn	About 800 tons produced mainly from oxidized zone contained 6.4% Cu, 2.74 opt Ag, and 0.17 opt Au.
20	Iron Queen	34°26'30"N 112°15'23"W	~1.75	Felsic tuffs and volcaniclastic rocks.	Prospect with inaccessible underground workings.	Zn, Cu, Au, Ag	Is about 2,000 ft S-SW of Bogge deposit. Siliceous ore reported to contain 2-2.75% Cu, 0.025 opt Au, and 1.0 opt Ag.
21	Pentland	34°25'28"N 112°16'14"W	~1.75	Fine-grained felsic tuffs and tuffaceous metasediments.	Prospect with inaccessible underground workings.	Cu, Zn	Occurs about 3,900 ft north of the Hackberry deposit.
22	Upshot	34°25'22"N 112°15'58"W	~1.75	Fine-grained felsic tuffs------	Prospect----------	Pb, Zn, Cu, Au, Ag	Is about 1,500 ft E-SE of Pentland prospect. About 150 tons of ore produced.
23	Carbine	34°25'04"N 112°16'58"W	~1.75	Fine-grained felsic tuff and tuffaceous metasediments.	Numerous prospect pits.	Cu	Occurs about 0.5 mi west of Hackberry deposit.
24	Hackberry	34°24'54"N 112°16'23"W	~1.75	Fine-grained felsic tuff------	Small, dormant underground mine.	Cu, Pb, Zn, Au, Ag	Between 1943 and 1945, 13,000 tons of ore were shipped grading 2.0% Cu, 3.5% Pb, 9.0% Zn, 0.113 opt Au, and 5.18 opt Ag.
25	Bell Ranch	34°28'01"N 112°17'11"W to 34°27'08"N 112°17'14"W	~1.75	Quartz-sericite and quartz-chlorite schists.	Prospect----------	Au	Prospect occurs in distal part of stratigraphically asymmetrical rhyolite dome complex.
26	Binghampton	34°27'19"N 112°01'36"W	~1.75	Felsic tuffs and pyroclastic rocks.	Dormant underground mine.	Cu, Au, Ag, Zn	About 175,000 tons of ore were produced. Early-day production yielded average grade of 3.0% Cu, 0.0013 opt Au, and 0.22 opt Ag from 150,000 tons of ore.
27	Copper Queen	34°27'22"N 112°01'22"W	~1.75	Exhalite occurs at contact between rhyolite tuff and tuff breccia, and younger andesite tuffs.	--------do.----------	Cu, Au, Ag, Zn	Production probably did not exceed 75,000 tons.
28	Stoddard	34°25'08"N 112°10'55"W	~1.75	Silicified chlorite schist, chert, and schistose quartz porphyry.	--------do.----------	Cu	Produced 14,000 tons of oxide ore grading 3.82% Cu.
29	Blue Bell	34°20'27"N 112°14'29"W to 34°20'44"N 112°14'23"W	~1.75	Fine-grained rhyolite tuffs and crystal tuffs.	--------do.----------	Cu, Au, Ag	More than 1 million tons of ore were produced grading 3.0% Cu, 0.05 opt Au, and 1.5 opt Ag.
30	De Soto	34°17'11"N 112°17'21"W	~1.75	Coarse rhyolitic pyroclastics and tuffs.	--------do.----------	Cu, Au, Ag	From 1890 to 1930, approximately 180,000 tons of ore were produced grading 3.75% Cu, 0.02 opt Au, and 1.0 opt Ag.
31	Unnamed prospect 2 mi SE of Cleator.	34°15'35"N 112°11'36"W	~1.75	Fine-grained felsic tuffs and quartz crystal tuffs.	Prospect----------	Cu	No recorded production.
32	Unnamed prospect 4 mi NW of Black Canyon City.	34°07'20"N 112°10'40"W	~1.75	Quartz crystal tuffs and felsic volcaniclastic rocks.	--------do.----------	Zn	Do.
33	Unnamed prospect 2 mi NW of Black Canyon City.	34°04'12"N 112°10'12"W	~1.75	Felsic tuffs----------	--------do.----------	ND	Do.
34	Kay	34°03'37"N 112°09'35"W	~1.75	Fine to coarse, felsic pyroclastics.	Dormant underground mine.	Cu, Zn, Au, Ag	Produced 2,271 tons of ore grading approximately 6.5% Cu, 0.062 opt Au, and 1.0 opt Ag.
35	Orizaba	34°00'33"N 112°04'50"W	1.70(?)	Calcareous mafic to intermediate tuffs intercalated with andesitic and rhyolitic flow rocks.	Dormant underground mine and prospects.	Cu, Zn, Au, Ag	Approximately 40,000 tons of ore were shipped grading 4.0% Cu.
36	Gray's Gulch	33°59'22"N 111°55'53"W	1.70(?)	Felsic tuffs, wackes, and volcaniclastics intercalated with slates.	Prospect pits----------	Cu, Zn	No recorded production.
37	Bronco Creek	33°56'48"N 111°51'44"W	1.70(?)	Fine-grained felsic tuffs and felsic crystal tuffs.	Prospect----------	Cu, Zn, Au, Pb, Ag	10,000 tons of pyritic ore grading 2.5% Cu and 0.16 opt Au were reportedly shipped for flux.
38	Copper Camp Creek.	33°57'51"N 111°34'00"W	~1.70	Felsic volcanic breccia--------	--------do.----------	Cu	No reported production.
39	Pittsburg-Tonto	34°00'01"N 111°17'41"W	~1.70	Fine-grained felsic tuffs and crystal tuffs.	--------do.----------	Cu, Pb	About 500 lbs of copper and 100 lbs of lead were produced.
40	Ernie's Tank	34°03'18"N 111°12'27"W	~1.70	Gray to purple phyllite intercalated with felsic and mafic tuffs and volcaniclastic rocks.	--------do.----------	Cu, Pb, Zn	No reported production.
41	Pranty's Cabin	34°04'09"N 111°10'03"W	~1.70	Rhyolitic lavas, explosive pyroclastics, and ash tuffs.	--------do.----------	Cu, Zn	Do.

Manuscript approved for publication, June 10, 1988

INTERIOR--GEOLOGICAL SURVEY, RESTON, VIRGINIA--1988

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