Arizona Bureau of Geology and Mineral Technology
FIELDNOTES
Vol. 18, No. 2 Summer 1988

by Jon E. Spencer
and John T. Duncan
Arizona Geological Survey

and William D. Burton
Cyprus Minerals Company
P.O. Box 3299
Englewood, CO 80155

The Copperstone Mine: Arizona's New Gold Producer

Arizona's annual gold output will almost double in 1988 as a result of production from Cyprus Minerals Company's Copperstone gold deposit in La Paz County, west-central Arizona. During 6 years of expected mine life, the deposit is predicted to yield approximately 510,000 troy ounces of gold worth $230 million, based on a value of $450 per ounce. Unlike many recent gold discoveries in the Southwest, Copperstone is a new discovery in an area not previously identified as a mineral district. In this article, the geology and regional setting of the Copperstone deposit are described. Although the deposit is still not completely understood, enough is known to warrant reassessment of estimates of mineral-resource potential in west-central Arizona.

Regional Geologic Setting

West-central Arizona and adjacent areas of California and southern Nevada contain some of the most spectacularly exposed detachment faults in the world. The term "detachment fault" is commonly applied to large-displacement, gently dipping (inclined) normal faults. In this region, hanging-wall rocks, or rocks overlying the detachment faults, were displaced northeastward relative to footwall rocks, rocks that underlie the faults. The faults originally dipped to the northeast, but are now rotated and warped to form undulating surfaces that are nearly horizontal over large areas.

The north- to northeast-dipping Moon Mountains detachment fault, exposed at the northern tip of the eastern Moon Mountains, separates two large, geologically distinct areas: to the northeast lie numerous detachment faults, such as those in the Buckskin, Rawhide, and northern Plomosa Mountains; to the south, in the Dome Rock, southern Plomosa, and most of the Moon Mountains, detachment faults are absent. The Copperstone gold deposit lies within the hanging wall of the Moon Mountains detachment fault and flanks the area of pervasive faulting.

Miocene (5- to 24-million-year [m.y.]-old) detachment faults in west-central Arizona are associated with numerous copper, iron, and gold deposits, especially in the Buckskin and Rawhide Mountains, that have yielded metals worth many millions of dollars (Figure 1; Table 1; Wilkins and Heidrick, 1982; Spencer and Welty, 1986). Copper-gold deposits associated with detachment faults typically lie along or within a few tens of meters of the faults; a few, however, are hundreds of meters above the faults. Detachment-fault deposits contain fractures and thick, irregular zones that are commonly filled with the minerals specular hematite, chrysocolla, quartz, barite, fluorite, calcite, and manganese oxides. Pyrite and chalcopyrite, which are commonly oxidized, are also present in many deposits.

The northeastern tip of the Moon Mountains is primarily composed of Mesozoic (63- to 240-m.y.-old) granitic rocks that form the footwall of the Moon Mountains detachment fault. Hanging-wall rocks are mostly metamorphosed Jurassic (138- to 205-m.y.-old) volcanic rocks. Older (Paleozoic; 240- to 570-m.y.-old) metamorphosed sedimentary rocks that are brecciated (composed of

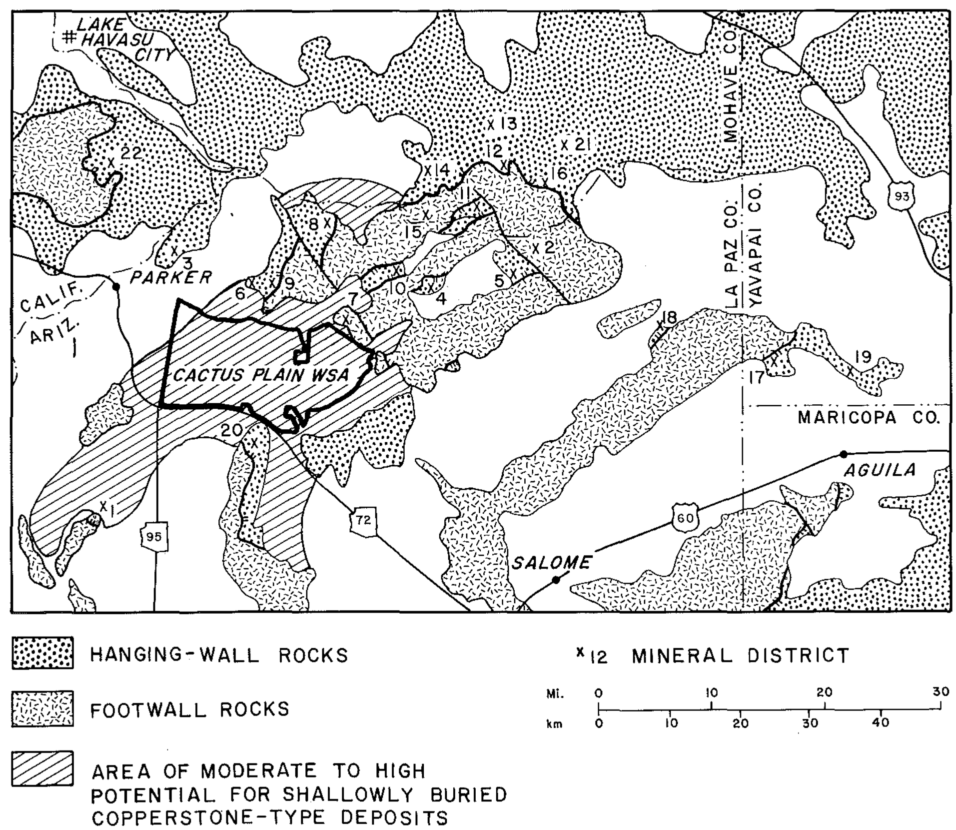

Figure 1. Map of part of west-central Arizona showing mineral districts where mineral deposits are known or suspected to be related to detachment faults. Middle Tertiary and older rocks are divided into hanging wall and footwall rocks, which lie above and below, respectively, regionally northeast-dipping detachment faults. Also shown is the outline of the Cactus Plain and Cactus Plain East Wilderness Study Areas. Numbers refer to mineral districts listed in Table 1.

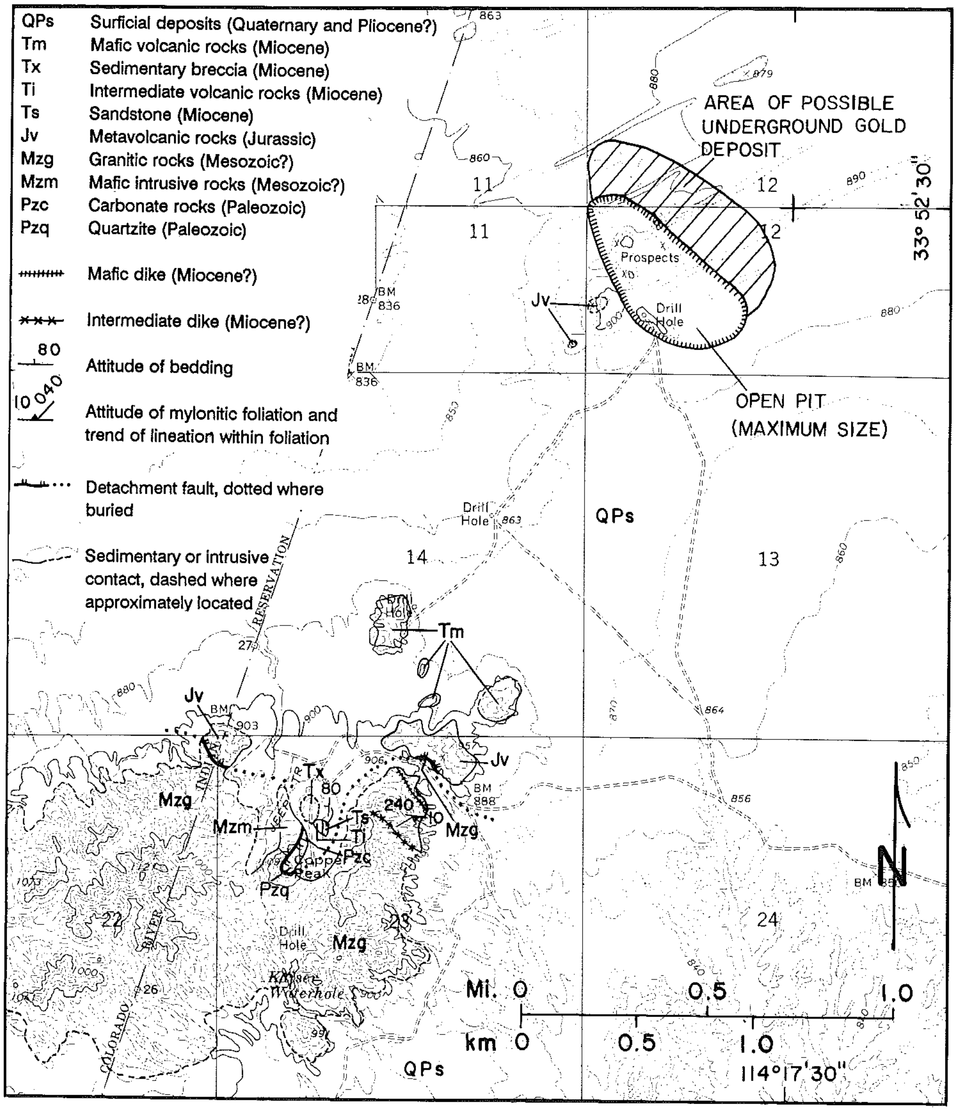

Figure 2. Geologic map of northeastern Moon Mountains showing location of Copperstone mine.

broken rock fragments) underlie Copper Peak; steeply dipping, younger (Miocene) volcanic and sedimentary rocks, including sedimentary breccias derived from the Jurassic volcanic rocks, are also present adjacent to Copper Peak (Figure 2). The copper-iron mineralization that characterizes detachment-fault deposits elsewhere in west-central Arizona is also evident in brecciated rocks along the Moon Mountains detachment fault at Copper Peak and at the edge of the Colorado River Indian Reservation.

Geology

The Copperstone mine is approximately 1½ miles northeast of exposed bedrock in the northeastern Moon Mountains (Figure 2). Bedrock exposures in several very small hills surrounded by alluvium contain evidence of gold mineralization and led to the discovery of the Copperstone deposit. Mineral deposits are present above and along a gently dipping contact that is probably a fault; the contact separates Jurassic metamorphosed volcanic rocks and overlying sedimentary breccias derived from them. The mineralized contact zone dips approximately 30° to the northeast, extends horizontally for 3,000 feet and at least 1,000 feet down dip, and is generally several tens of feet thick. The sedimentary breccia and a volcanic rock that contains vesicles (relict gas bubbles) are almost certainly Miocene in age and are mineralized, indicating that mineralization is Miocene or younger.

Drill-core samples reveal that some brecciation occurred after quartz veins were formed; however, numerous northwest-trending quartz-amethyst veins exposed in the mine pit are not brecciated. Steeply dipping, northwest-striking fractures and narrow shear zones exposed in the mine pit locally cut quartz-amethyst veins and contain subhorizontal slickenside lineations, which are smooth and polished striations that result from friction along a fault plane.

Gold is present where quartz and specular hematite are abundant in the breccia zone and locally within veins in the metamorphosed volcanic rocks. Chrysocolla, barite, earthy red hematite, and malachite are also common in the gold-mineralized zone. Fluorite, adularia, magnetite, calcite, chalcopyrite, pyrite, and manganese oxides are present in smaller quantities. Gold, however, is rarely visible. The presence of quartz, hematite, and chrysocolla is a good indicator of gold mineralization.

Fluid-Inclusion Characteristics

Fluid inclusions are bubbles of liquid and gas that are commonly trapped inside minerals during mineral formation. The composition of fluid inclusions in mineral deposits reflects the composition of the aqueous fluids that formed the deposits. One can determine the salinity of the inclusions by determining the freezing temperature of the fluid within them. The minimum temperature of the fluid at the time it was trapped can be determined by heating the sample until the two phases (liquid and gas) in the inclusion become one. Fluid inclusions in quartz-amethyst from the Copperstone mine contain between 16 and 22 percent sodium-chloride equivalent (by weight) and were trapped at minimum temperatures between 200° and 260° C. These characteristics are similar to those of other mineral deposits along Miocene detachment faults in west-central Arizona, but are substantially different from those of most other types of deposits, such as epithermal-vein gold deposits (Figure 3; Wilkins and others, 1986).

Origin

The following characteristics of the Copperstone deposit suggest that it originated from the same processes that formed mineral deposits along numerous other Miocene detachment faults: (1) fluid-inclusion salinities and temperatures of entrapment; (2) abundant specular hematite with less abundant copper minerals such as chrysocolla, malachite, and chalcopyrite; (3) geographic proximity to a detachment fault; and (4) probable Miocene age. Two characteristics of the Copperstone deposit, however, differ from those of other detachment-fault deposits: abundance of quartz-amethyst veins and abundance of gold. These authors believe that most evidence at the Copperstone deposit supports a relationship between mineralization and detachment faulting.

A working model for the origin of the Copperstone deposit is as follows: hot, saline, aqueous fluids containing dissolved gold, copper, iron, and other elements moved updip along the north- to northeast-dipping Moon Mountain detachment fault. These fluids encountered highly porous and permeable sedimentary breccias in the hanging wall of the detachment fault and began ascending through the breccia zone. As a result of cooling or mixing with more oxygen-rich, shallow-level ground water, largely within the sedimentary breccias, gold and

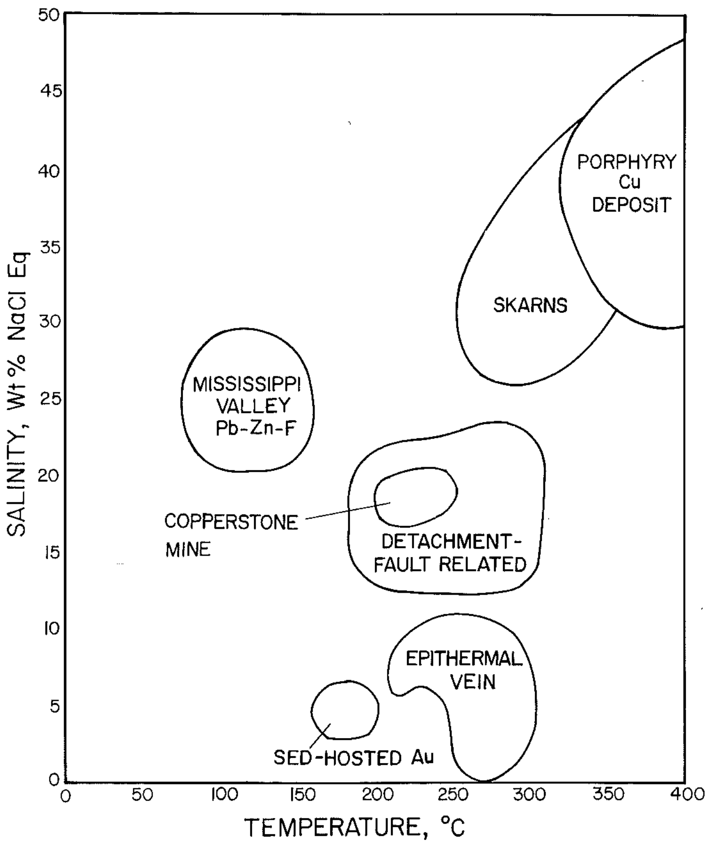

Figure 3. Diagram of salinity and homogenization temperature fields for fluid inclusions from several major mineral deposits, including those associated with detachment faults. Fluid inclusions from the Copperstone deposit clearly fall within the field of other detachment-fault-related deposits. Many geologists suspected that the Copperstone deposit was an epithermal-vein deposit, as are many other gold deposits in the Southwest; fluid-inclusion data, however, strongly suggest otherwise. Modified from Wilkins and others (1986), with additional data from the Copperstone mine.

Table 1. *Value of production for commodities from mineral districts in west-central Arizona that are known or suspected to be related to detachment faults. Manganese mineral deposits, although not clearly understood, are suspected to be related to detachment faults. District locations are shown on Figure 1.*

District	Commodities*	1986 Value**
1. Copperstone	Au (reserves)	$189,306,900
2. Alamo	Cu, Pb, Ag, Au	72,303
3. Cienega	Cu, Ag, Au	5,571,167
4. Clara	Cu, Ag, Au	3,066,661
5. Lincoln Ranch	Mn	18,960,000
6. Mammon	Cu, Ag, Au	93,913
7. Midway	Cu, Ag, Au	43,743
8. Planet	Cu, Ag, Au	12,771,828
9. Pride	Cu, Ag, Au	37,679
10. Swansea	Cu, Ag, Au	17,471,085
11. Black Burro	Mn	261,490
12. Cleopatra	Cu, Pb, Ag, Au	1,118,459
13. Lead Pill	Cu, Pb, Ag, Au	303,365
14. Mesa	Mn	47,400
15. Owen	Cu, Pb, Zn, Ag	107,561
16. Rawhide	Cu, Pb, Zn, Ag	116,573
17. Bullard	Cu, Ag, Au	1,763,481
18. Burnt Well	(unknown)	(minor)
19. Harris	Mn	79,395
20. Northern Plomosa	Cu, Pb, Ag, Au	2,123,413
21. Artillery	Mn	75,135,320
22. Whipple	Cu, Pb, Zn, Ag, Au	683,550
TOTAL		$329,135,287

* Ag = silver; Au = gold; Cu = copper; Mn = manganese; Pb = lead; Zn = zinc.
** Values do not add to total because of rounding.

other elements precipitated from the fluids to form the Copperstone deposit.

Implications for Land-Use Planning and Management

The presence of the Copperstone gold deposit in a geologic setting that is characteristic of large areas of west-central Arizona indicates that the mineral-resource potential of this area in the State is greater than previously suspected.

The Copperstone deposit was probably not discovered until recently because it was almost entirely concealed by young surficial deposits. Undiscovered mineral deposits similar to Copperstone may also be concealed beneath other surficial deposits, such as those covering nearby Cactus Plain (Figure 1). Application of more sophisticated geophysical techniques may eventually result in discovery of such deposits. Many areas in west-central Arizona, such as the Cactus Plain and Cactus Plain East Wilderness Study Areas, are presently under consideration for Federal wilderness-area status. If designated to be managed as wilderness, these areas would no longer be open to mineral exploration or mining activity.

Mineral deposits associated with detachment faults have only been recognized as a distinct deposit type during the past 10 years. The recent discovery of the Copperstone deposit and recognition of its association with a detachment fault are generating renewed interest in detachment-fault-related deposits and in areas where such deposits might be located. Future improvements in our understanding of Arizona geology and future mineral-deposit discoveries will undoubtedly lead to renewed interest in areas that presently receive little attention from research or exploration geologists.

References

Spencer, J.E., and Welty, J.W., 1986, Possible controls of base- and precious-metal mineralization associated with Tertiary detachment faults in the lower Colorado River trough, Arizona and California: Geology, v. 14, p. 195-198.

Wilkins, Joe, Jr., Beane, R.E., and Heidrick, T.L., 1986, Mineralization related to detachment faults; a model, *in* Beatty, Barbara, and Wilkinson, P.A.K., eds., Frontiers in geology and ore deposits of Arizona and the Southwest: Arizona Geological Society Digest, v. 16, p. 108-117.

Wilkins, Joe, Jr., and Heidrick, T.L., 1982, Base and precious metal mineralization related to low-angle tectonic features in the Whipple Mountains, California and Buckskin Mountains, Arizona, *in* Frost, E.G., and Martin, D.L., eds., Mesozoic-Cenozoic tectonic evolution of the Colorado River region, California, Arizona, and Nevada: San Diego, Cordilleran Publishers, p. 182-203.