Preliminary Descriptive Deposit Model for Detachment-Fault-Related Mineralization

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INTRODUCTION

Mineralization related to detachment faulting has only recently been recognized as a distinct deposit type, even though such deposits have been mined since the 1860's. These deposits have characteristic mineral assemblages, alteration patterns, ore fluid types, and structural controls that differ considerably from those of other deposit types found in the Basin and Range province of the Western United States. However, detachment-fault-related mineralization is not widely known, having been described but twice in widely circulated journals (Spencer and Welty, 1986; Roddy and others, 1988); most of the detailed studies have appeared as publications of the Arizona Geological Survey and the Arizona Geological Society.

Awareness of the unique character of these deposits has been hampered by confusion with other types of epithermal mineralization that may or may not occur near a low-angle or detachment fault, such as the Cyclopic deposit in northwest Arizona (Myers and Smith, 1986) or the Mesquite deposit in southeastern California (Manske and others, 1988). This discussion sets out the distinguishing characteristics of detachment-fault-related mineralization vis-à-vis other types of epithermal mineralization in the region and provides a justification for the new deposit model presented (K.R. Long, this volume). This deposit model is considered preliminary because this deposit type has yet to be fully investigated and has, thus far, only been recognized in a detachment-faulted terrane encompassing parts of west-central Arizona, southeastern California, and southernmost Nevada (fig. 35).

DETACHMENT-FAULT-RELATED MINERALIZATION

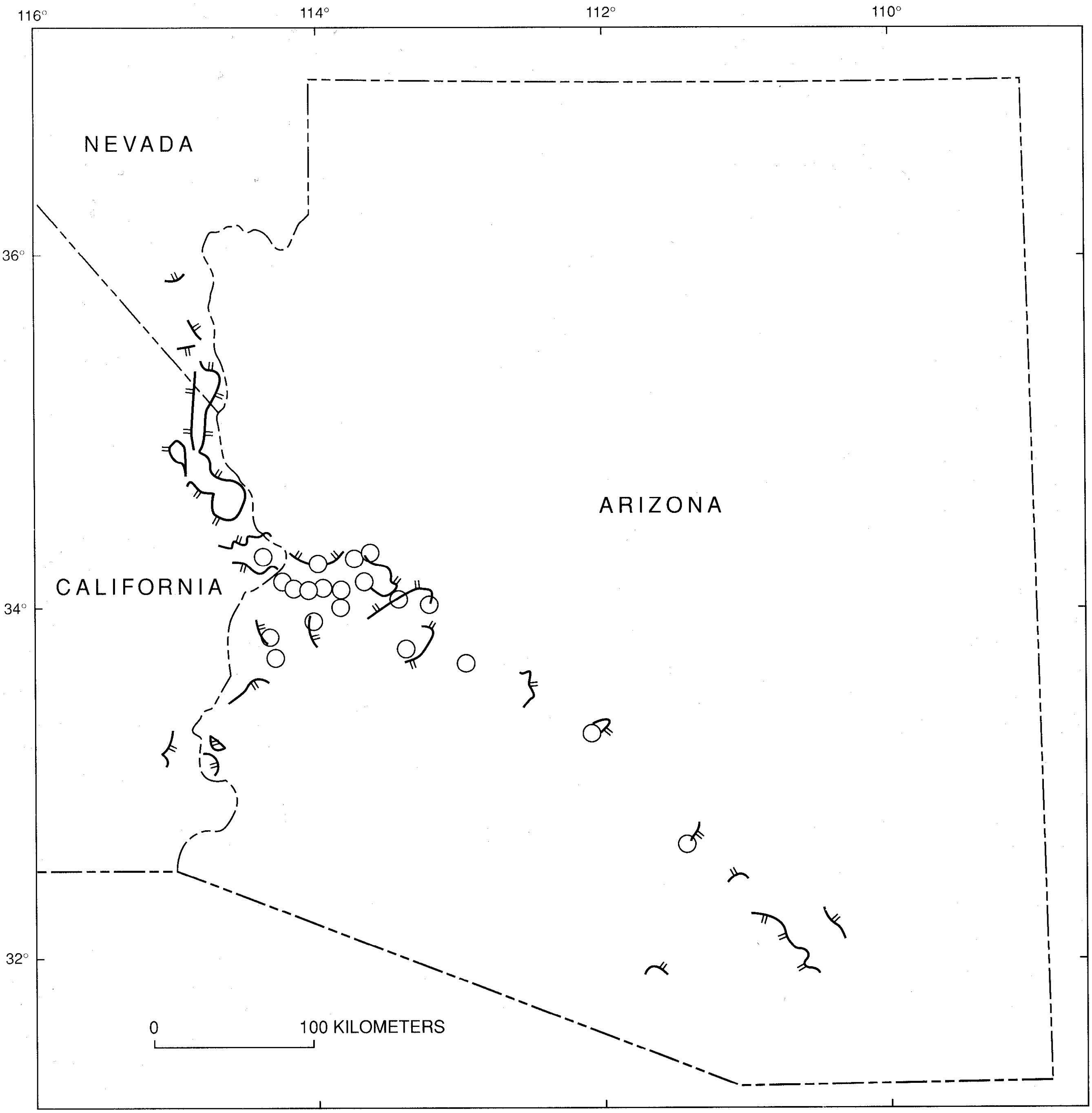
Detachment faults are low-angle (up to 30°) normal faults of regional extent that have accommodated significant regional extension by upward movement of the footwall (lower-plate) producing horizontal displacements on the order of tens of kilometers. Common features of these faults are supracrustal rocks in the upper-plate on top of lower-plate rocks that were once at middle and lower crustal depths, mylonitization in lower-plate rocks that are cut by the brittle detachment fault, and listric and planar normal faults bounding half-graben basins in the upper-plate (Davis and Lister, 1988).

The detachment fault and structurally higher normal faults locally host massive replacements, stockworks, and veins of iron and copper oxides with locally abundant sulfides, veins of barite and (or) fluorite, and veins of manganese oxides (Spencer and Welty, 1986; fig. 36). Bedded manganese oxides occur in sedimentary rocks deposited in the half-graben basins and are generally associated with fault veins of manganese oxides. These bedded manganese deposits should be described separately as another model (lacustrine manganese). Intense chloritic alteration of footwall mylonitic rocks and potassium feldspar replacement of upper-plate rocks are common alteration types that are not always accompanied by mineralization.

This mineralization is termed detachment fault related not simply because it is strongly controlled by detachment-fault structures, but also because it is apparently related to the formation of detachment faults themselves (Roddy and others, 1988). Early chloritic alteration and associated sulfide mineralization appears to result from retrograde metamorphism as hot lower-plate rocks are brought up to shallower depths. Potassium feldspar alteration and oxide mineralization appear to be related to the upward circulation of saline brines derived from syntectonic basins along the detachment fault into more steeply dipping upper-plate normal faults. This fluid movement may have been driven by heat derived either from lower-plate rocks or from syntectonic microdiorite to rhyolite intrusives (Reynolds and Lister, 1987).

DISTINGUISHING CHARACTERISTICS OF DETACHMENT-FAULT-RELATED MINERALIZATION

Features of detachment-fault-related mineralization that distinguish it from other deposit types are listed below. Further details are available in Spencer and Welty



EXPLANATION

Detachment fault

Known detachment-fault-related deposits

Figure 35. Major detachment faults and detachment-fault-related mineral deposits in Arizona, southeastern California, and southernmost Nevada.

(1986), Roddy and others (1988), and Spencer and Reynolds (1989).

1. Deposits are controlled by structures formed during detachment faulting. These include the low-angle, detachment-fault system, high-angle faults in the lower-plate just below the detachment fault, and low- to high-angle normal faults in the upper-plate.
2. Deposits are often brecciated or deformed by movement along or above the detachment fault.
3. Chlorite-epidote-calcite alteration occurs along and below the detachment fault. These altered zones sometimes contain base-metal sulfides and barite.
4. There is massive potassium feldspar replacement of upper-plate rocks. This alteration appears to generally precede ore formation and is not always spatially associated with mineralization.
5. Weak sericite-silica alteration of wall rock is sometimes present around barite-fluorite veins.
6. Most mineralization consists of iron and copper oxides, principally specular to earthy hematite and chrysocolla. Common gangue minerals are chalcedonic to amethystine quartz, ferrous to manganiferous calcite, barite, fluorite and manganese oxides. Distal barite-fluorite veins consist of variable proportions of barite, fluorite, and manganese oxides. Common gangue minerals are quartz and manganiferous calcite.
7. Fluid inclusions have moderate homogenization temperatures (150 to 350 °C) and salinities (10 to 23 equivalent weight percent NaCl), compatible with precipitation from connate brines. Fluid inclusions from barite-fluorite veins have lower homogenization temperatures (90 to 200 °C) and are somewhat less saline (6 to 20 equivalent weight percent NaCl), compatible with precipitation from variably cooled and diluted connate brines.
8. Host rocks are enriched in Cu, Pb, Zn, Au, Ag, and Ba and are depleted in Mn, Sr, Ni, and Rb. Elements characteristic of epithermal environments, such as As, Sb, Hg, and Tl, occur in very low, background-level concentrations.

DEPOSIT TYPES COMMONLY CONFUSED WITH DETACHMENT-FAULT-RELATED MINERALIZATION

Epithermal gold-silver deposits that occur along or near low-angle faults might be mistaken for detachment-fault-related mineralization. Several possible cases can be identified:

1. Epithermal deposits found in metamorphic rocks (for example, Mesquite, California; Manske and others, 1988).
2. Epithermal deposits that are overprinted by younger detachment-fault-related mineralization (for example, Cyclopic, Arizona; Myers and Smith, 1986).

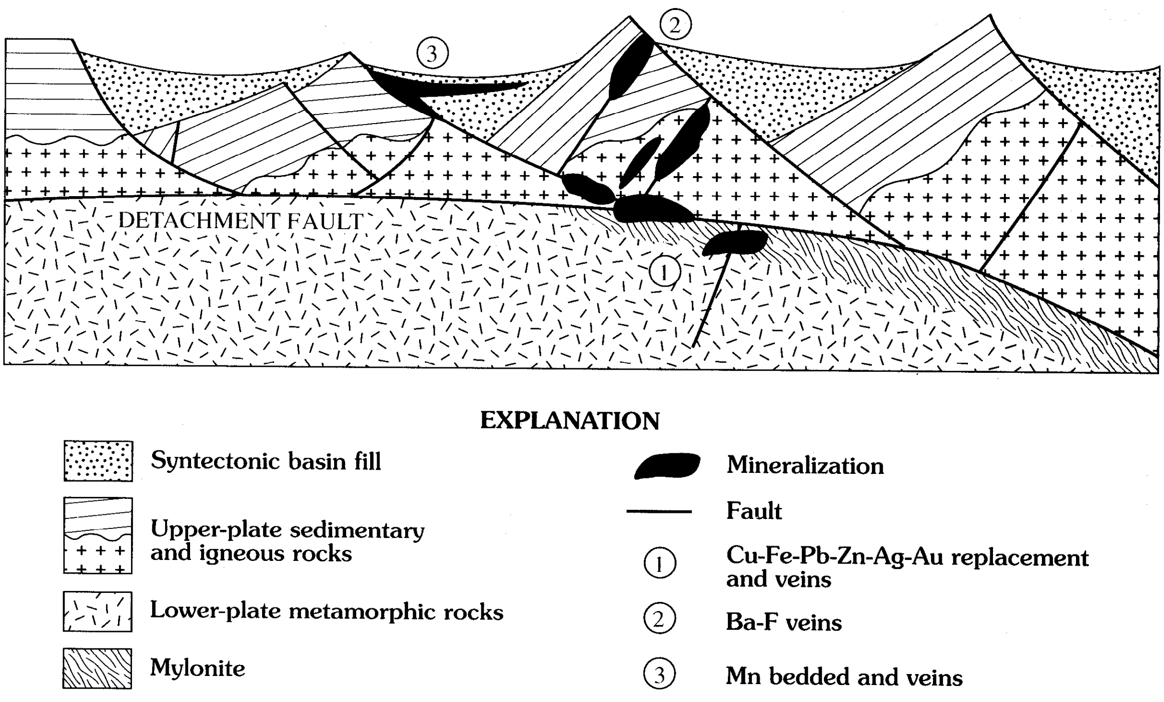


Figure 36. Schematic diagram (not to scale) showing structural position of detachment-fault-related polymetallic mineralization, Ba-F-Mn veins, and lacustrine manganese mineralization in detachment-faulted terranes.

3. Epithermal deposits that overprint detachment-fault-related mineralization or that were emplaced during detachment faulting (for example, Bullfrog, Nevada; Jorgeson and others, 1989).
4. Epithermal deposits that are significantly younger than detachment faulting but are controlled by detachment-fault structures (no known examples in the published literature).

Epithermal deposits can be distinguished from detachment-fault-related deposits by their characteristic ore mineralogy, alteration minerals and patterns, geochemical signatures, and fluid-inclusion compositions, as described in the deposit model for hot spring Au-Ag (Berger, 1986b). Principal distinguishing characteristics are the following:

1. Ore mineralogy consists of base- and precious-metal sulfides with few or no primary oxide minerals. Gangue quartz is not usually amethystine, and gangue calcite is poor in iron and manganese.
2. Extensive propylitic and (or) argillic alteration of upper-plate host rocks is observed with only local potassic alteration.
3. Low-salinity (<6 equivalent weight percent NaCl), moderate homogenization temperature (200 to 300 °C) fluid inclusions are observed.
4. Anomalous concentrations of the elements As, Sb, Hg, and Tl, which are characteristic of epithermal deposits, are present.

SIZES AND GRADES OF DEPOSITS

Available data on sizes and grades of detachment-fault-related mineral deposits consist mostly of production statistics originally collected by the U.S. Bureau of Mines and reported by the Arizona Geological Survey (Keith and others, 1983; Spencer and Welty, 1989). The only reserve data available are for recently explored deposits, such as Copperstone, Arizona (Spencer and others, 1988). Attempts to model tonnages and grades for detachment-fault-related polymetallic deposits using cumulative production data (table 10) were not successful. Few of these deposits produced all of the metals that occur in this deposit type, making it difficult to model deposit grades. In fact, indications are that there may be two subtypes of detachment-fault-related mineralization—a Cu-Au type and a Pb-Zn-Ag type—but further research is required to confirm this.

In any case, grade and tonnage models based on the production data listed in table 10 would not give an accurate indication of the range in sizes and grades of these deposits that could be expected to be encountered in a modern exploration program. Not only were not all metals recovered, but also many of these ores were concentrated in part by hand. In hand sorting, a large quantity of waste is typically rejected prior to sending ore to the concentrator, and these rejects are not always included in recorded production tonnages. Thus, the grades computed from production statistics are not likely representative of the true grade of the ore mined. Further, these were underground mines; thus, in comparison with the tonnages and grades that might be estimated for a modern open-pit operation, these older orebodies were smaller in size and higher in grade.

A better sense of the potential size and grade of these deposits is indicated by recently reported reserves for deposits that have been excluded from table 10 as a result of their lack of production history. These are Copperstone (Spencer and others, 1988), a recent producer with reserves of 4.2 million short tons of 0.077 troy ounce per ton Au ore as of December 31, 1988, having produced 62,800 troy ounces Au prior to that date (Cyprus Gold Co., 1989); and Newsboy, a recent discovery in Arizona, with reserves of 1.5 million short tons of 0.045 troy ounce per ton ore (H. Dummett, oral commun., 1989).

A number of deposits have been excluded from table 10 because their classification as detachment-fault-related deposits is controversial. These include Picacho, California (Van Nort and Harris, 1984), and Silver, Arizona (Bradley, 1986).

Table 10. Grades and tonnages for detachment-fault-related polymetallic deposits

[Tonnages in short tons; copper, lead, and zinc grades in percent; silver and gold grades in troy ounces per short ton. Country and sate abbreviations explained in app. B]

Deposit	Country	Tonnage	Copper grade	Lead grade	Zinc grade	Silver grade	Gold grade	Source[1]
Alamo-Bluebell	USAZ	692	2.80	1.10		.47	0.12	2
ArtilleryPeak	USAZ	500	1.30			1.20		1
Bullard	USAZ	17,000				.35	.21	1
Cienaga	USAZ	19,092	4.50			.08	.63	2
Clara	USAZ	49,728	4.70			.03		2
Cleopatra-Cleopatra	USAZ	14,744	1.50			.23	.11	2
Cleopatra-Kimble	USAZ	4,482	.30			.03	.01	2
Cleopatra-Silverfield	USAZ	863	.90	.03		9.50	.06	2
Harquahala (Eastern)	USAZ	21,000	.14			.35	.13	1
Lead Pill	USAZ	1,451	.96	13.90		1.50	.36	2
Mammon	USAZ	841	5.20			.17	.07	2
Midway–Battleship	USAZ	15	4.00			.07		2
Midway–GreenStreak	USAZ	189	1.30			.11	.20	2
Midway–Mammoth	USAZ	10	16.30			1.30	.80	2
Moon Mountains	USAZ	300				.33	2.70	1
Northern Plomosa	USAZ	7,500	2.30	.16		.93	.67	1
Osborne	USAZ	86,000	.79	4.50		2.30	.15	1
Owens	USAZ	792	.11	3.90		13.00	.13	2
Picacho	USAZ	100	1.20			1.00		1
Planet-Mineral Hill	USAZ	970,756	.68					2
Planet-Planet	USAZ	39,015	8.00			.01	.01	2
Pride	USAZ	38	.03			.16	2.00	2
Rawhide	USAZ	708	.74	18.4	1.60	11.50	.05	2
Salt River Mountains	USAZ	15,000	.09			.33	.47	1
Swansea	USAZ	544,918	2.40			.06		2
Whipple	USCA	5,000	2.30	.01		1.90	.26	3

[1]Sources: 1 (Keith and others, 1983), 2 (Spencer and Reynolds, 1989), and 3 (Spencer and Welty, 1986).