# TECTONIC SETTING OF THE PORPHYRY COPPER DEPOSITS OF SOUTHEASTERN ARIZONA AND SOME ADJACENT AREAS

by

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Abstract

The major mineral deposits of southeastern Arizona and the adjacent parts of Sonora, New Mexico, and south-central Arizona occur in tectonically complex parts of the Basin and Range geologic province. This complexity is the cumulative result of at least three periods of severe and diverse kinds of regional deformation, as well as of some local disturbances. The oldest faults of the region are major northwest-trending basement flaws that were recurrently active. Next, the Laramide orogeny resulted in the development first of thrust faults and then of magmas and mineralizing fluids. Finally, the Basin and Range block faults formed. Although most of the major mineral deposits of the region, among them the renowned porphyry copper deposits, are temporally associated with the Laramide orogeny, they are spatially associated with the oldest faults. Furthermore, conditions arising from the youngest period of deformation have modified the deposits in many ways. A synthesis of the entire geologic development of the region thus is a vital key to understanding at least the distribution of the major ore deposits, if not also some of their individual features.

During the Precambrian, at least some of the major northwest-trending faults were formed in what are now the crystalline basement rocks. This early movement and some subsequent movement probably was left slip, and the amount of the earliest horizontal movement on one fault may have been about 15 km (10 mi). Some faults of this system were activated or reactivated during the Triassic, Jurassic, and Early Cretaceous; many of them were reactivated during the Paleocene; and some segments were reactivated during mid-Tertiary and even later times. These northwest-trending basement flaws were probably the main conduits for upward-moving magmas and mineralizing fluids at least since the Triassic, for many stocks were emplaced along the faults and all major mineral deposits lie within a few kilometres of the faults. A critical feature of these faults is that they were not active synchronously in Triassic and younger times, but that they did provide a structural anisotropy which guided the development of many subsequent features. Consequently, the geologic record varies, not only from fault to fault, but also from one segment of a major fault to another. Under these circumstances it is no wonder that their extent and perhaps their significance has not been fully appreciated, although they have been flagged by such workers as Harrison Schmitt, Kenyon Richard, Harold Courtright, and Evans Mayo.

During Late Cretaceous time, and perhaps somewhat later toward New Mexico, a regional thrust sheet formed near the surface in response to northeast-directed compressive stress. The allochthon extends northwest, west and south of the Little Dragoon Mountains near Benson, Arizona, and it extends east at least to the New Mexico border, about 15 km (10 mi) south of Interstate Highway 10, and probably on eastward to the El Paso area. The allochthon consists of several subordinate thrust sheets that are broken by many minor thrust faults, tear faults, and disharmonic normal faults; locally the thrust sheets are also folded.

The role of the thrust faults in the distribution of the major mineral deposits is secondary to that of the northwest-trending basement flaws, apparently because the thrust faults were relatively shallow features. In most places mineralization and plutonism of Laramide age followed the period of major thrust faulting. That being the case, the actual amount of northeastward thrust movement is of little consequence to the mineralization. Major ore-bodies probably occur in the allochthon because it was present in the zone of appropriately decreasing pressure and temperature near the surface and because it contains many rocks having a composition favorable to mineral deposition. However, in some mining districts,

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such as Tombstone and Helvetia, the minor structures related to the thrust faults produced second-order and third-order conduits for mineralizing fluids migrating away from the master faults as they moved upward. Nevertheless, the thrust faults and mineralization may be related indirectly, for the compressive deformation of the rocks at the surface is probably genetically linked to the generation of magma and mineralizing fluids at depth through the underthrusting of an extensive crustal plate. Further speculations in this direction are more appropriate to the tectonic synthesis of a much larger region than southeastern Arizona.

During Oligocene and later time the region was deformed again, this time in response to east-west-oriented tension. This stress condition led to the development of normal faults, grabens, and tilted blocks typical of the Basin and Range province, and it permitted upward movement of additional magma and locally also of some ore fluids. In a few places domes of gneiss and fault blocks were raised. Where older faults were suitably oriented, the normal faults were deflected from a north-south orientation. Thus, some segments of the basement flaws were reactivated as normal faults. Some of the uplifted areas rose so rapidly and so far that the gross topographic imbalance led to gravity sliding and low-angle normal faulting. Where the gravity faults were subparallel to thrust fault segments these segments were reactivated. Where the gravity faults cut rocks that were previously thrust faulted, intruded, or mineralized, the earlier features were moved piggyback fashion by the younger gravity faults, such as happened on the San Xavier fault on the east flank of the Sierrita Mountains and in the Rincon Mountains. This last period of major deformation, then, guided the development of the present topography, helped to determined the depth of exposure or of burial of mineral deposits, and influenced the development and distribution of secondary mineralization.

From the foregoing review of the tectonic development of southeastern Arizona and the relations between this development and mineralization several conclusions may be drawn: (1) In order to understand the distribution of the major mineral deposits both the regional geology and the local geology near the deposits must be known; it is as important to know the total geologic development of an area as it is to know just the events of the period of major mineralization. (2) In southeastern Arizona and adjacent areas the distribution of the northwest-trending basement flaws appears to be a key to the distribution of the major orebodies. The most favorable segments for mineralization are those which contain a scattering of intrusives and host rock alike, not those which are obliterated by intrusive bodies or devoid of such bodies. Geophysical methods may be useful in testing the presence and distribution of the master faults herein outlined, for even where concealed they may separate rocks of contrasting geophysical signature. (3) Prime ground for mineralization typically lies in favorable rock along secondary structures a few kilometres from the master faults. Perhaps a systematic study of the direction of ore fluid movement and of the optimum distance from the master faults (and/or depth at which mineralization occurred) would provide guidance to further restricting exploration targets. (4) More must be learned of events and conditions at the depths in which ore fluids and metal sources arise, so that regional tectonic patterns may be better utilized in economic exploration.