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BELTS OF LARAMIDE-AGE INTRUSIVE ROCKS AND FISSURE VEINS IN SOUTH CENTRAL ARIZONA[1]

by

Eberhard A. Schmidt
Department of Geosciences, University of Arizona
Tucson, Arizona

INTRODUCTION

A review of the literature in conjunction with field data collected in the Tortilla-Dripping Spring Mountain area during the course of the writer's doctoral dissertation work established a significant spatial relationship between the trends of Laramide-age hypabyssal rocks and mineralized fissure veins.

Several subparallel zones are recognized trending ENE to WNW across Pima, Pinal, and Gila Counties of Arizona. Individual zones measure from less than 5 miles up to 10 miles in width, but their observable length is limited by the extent of post-Laramide volcanic and sedimentary cover. Wherever observed, the intrusive zones clearly transect the northwest-trending Tortilla, Dripping Spring, Galuiro, Silver Bell, and Sacaton Mountains cutting rocks ranging from older Precambrian to Cretaceous in age.

The area under discussion extends from Tucson in the south to Superior in the north, from the Papago Indian Reservation in the west to Copper Creek in the east (Figure 1). The writer realizes that these boundaries are arbitrary and that similar intrusive belts and mineralized zones as here described do exist elsewhere in Arizona.

The intrusive rocks in each belt range in composition from quartz diorite to dacite porphyry and fall into the 58-71 m.y. time span (upper Cretaceous - lower Eocene). Every belt contains one or more stocks, numerous comagmatic dikes, and a systematic arrangement of mineralized fissure veins and fractures. The dikes and fissure veins outline the belts exceptionally well, whereas the larger intrusive masses indicate a less obvious alignment.

Even though the studied area has been extensively subjected to northwest-trending Basin and Range block faulting in mid-Tertiary time, the Laramide belts, as here presented, have not lost their regularity. However, lateral displacements of several miles are locally indicated.

The following belts are described in sequence from north to south:

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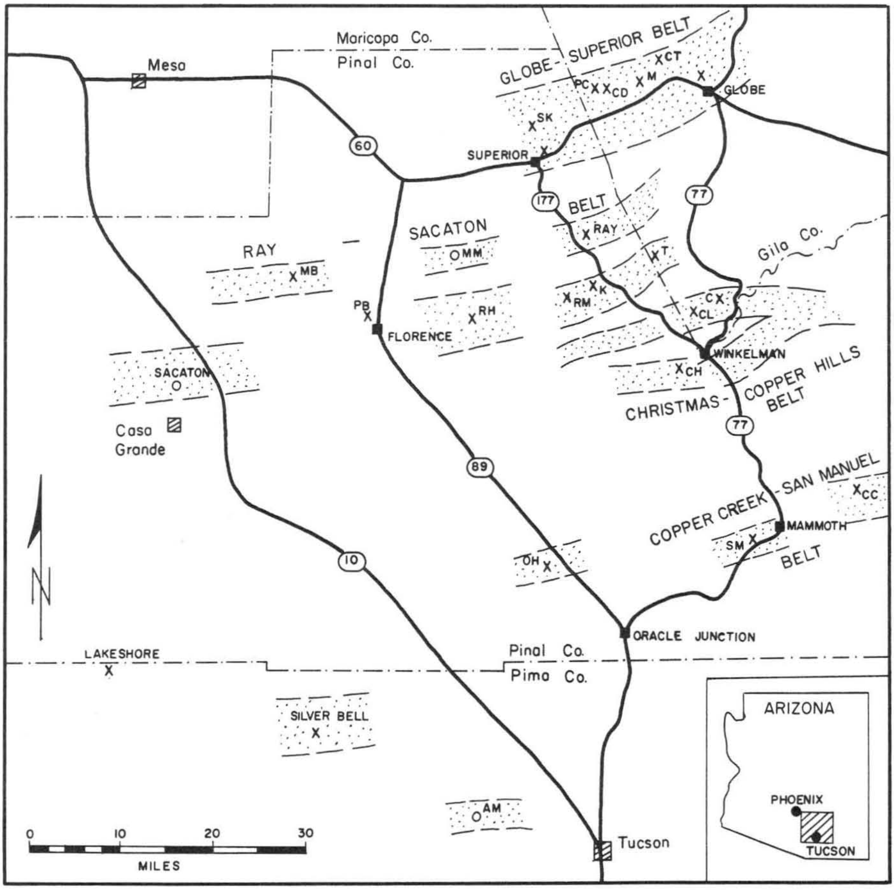

AM - Amole	K - Kelvin	RH - Red Hills
C - Christmas	M - Miami-Inspiration	RM - Rare Metals
CC - Copper Creek	MB - Mineral Buttes	SK - Silver King
CD - Castle Dome	MM - Mineral Mountain	SM - San Manuel
CH - Copper Hills	OH - Owl Head	T - Troy
CL - Chilito	PB - Posten Butte	
CT - Copper Cities	PC - Pinto Creek	

Figure 1.--Belts of Laramide-Age Intrusive Rocks and Fissure Veins in south central Arizona.

1. Globe - Superior belt;
2. Ray - Sacaton belt;
3. Christmas - Copper Hills belt;
4. Copper Creek - San Manuel belt;
5. Silverbell district.

GLOBE - SUPERIOR BELT

The most prominent feature of this zone is the Schultze granite (62 m.y.) and accompanying intrusive masses with which the copper deposits of Miami-Inspiration, Copper Cities, Castle Dome, and Pinto Creek are genetically associated (Peterson, 1951, 1962; Olmstead and Johnson, 1966; Simmons and Fowells, 1966). Many of the smaller intrusive bodies show a preferred N 70°E elongation. The same northeast trend is indicated by the prominent fault vein system in the Globe area.

The western extension of the Globe - Superior belt is realized in the east-trending Magma vein at Superior and the elongated intrusive masses at Silver King and Haunted Canyon. The east-northeast trending fault vein system in the Belmont district south of Superior is also part of this structural belt. Unfortunately, a large part of the Globe - Superior mineral belt is covered by a thick sequence of the 20 m.y. old Superior dacite ignimbrite complex and is thus removed from direct observation.

RAY - SACATON BELT

The Ray - Sacaton belt is defined by several quartz monzonite-granodiorite intrusive masses, numerous sub-parallel dike swarms, mineralized fissure veins and limonite-coated fractures. The northern zone of this belt includes the Ray copper mine with the Granite Mountain porphyry (60-63 m.y.), the Teapot Mountain porphyry, and several east-west trending dike swarms, the Mineral Mountain quartz monzonite stock, and the Mineral Butte stock with numerous comagmatic east trending dikes and fissure veins. In the Ray area the zone trends mainly northeasterly ("porphyry break," Metz and Rose, 1966), whereas at its western termination the zone trends east-west.

The southern zone of the Ray - Sacaton belt begins with the Troy granodiorite stock (71 m.y.) and several east trending dike rocks in the Dripping Spring Mountains, and continuous past Kelvin, Red Hills, and Florence to the Sacaton Mountains. This zone contains the Grayback granodiorite pluton (63 m.y.) and comagmatic east trending dike swarms (63 m.y.), abundant ENE to WNW trending fissure veins in the Kelvin, Rare Metals mine, and Red Hills area, and various easterly trending quartz diorite intrusive bodies (69 m.y.) in the Tortilla Mountains. The newly discovered copper deposits of ASARCO and Conoco in the Sacaton and Florence areas are within the southern zone of the Ray-Sacaton mineral belt.

A possible eastern extension of the Ray belt is suggested by the northeast trending veins and dikes in the Pinal Ranch quadrangle between Ray and Globe (Peterson, 1963). The structures conform to the foliation direction of the older Precambrian Pinal Schist. Similarly, the fissure veins and dikes in the Kelvin area follow to some degree the foliation in the older Precambrian Oracle Granite.

CHRISTMAS - COPPER HILLS BELT

This structural zone begins east of the Gila River in the upper Cretaceous andesite complex and is well defined by numerous quartz monzonite-granodiorite dikes and elongated intrusive masses. Northeast of Winkelman, the west trending main belt splits into two segments. The northern segment includes the Christmas and Chilito mineral deposits, various granodiorite stocks (62 m.y.), and dike swarms in the southern Dripping Spring Mountains, as well as dike swarms and elongated quartz diorite intrusive bodies in the Hackberry area of the Tortilla Mountains.

The southern segment swings southward past Winkelman and continuous across the San Pedro River to the Copper Hills area. This segment includes several elongated granodiorite and quartz diorite intrusive masses (68 m.y.) and numerous associated dikes and fissure veins.

The western continuation of the Christmas - Copper Hills belt is poorly defined because of extensive eluvial cover in the older Precambrian granite complex. To the east, the belt dies out in the vicinity of Reed Basin (Willden, 1964).

COPPER CREEK - SAN MANUEL BELT

Even though a direct structural connection between the Copper Creek and San Manuel - Kalamazoo mineral deposits is not evident from surface exposures, they are here included in one mineral zone. At Copper Creek there are several intrusive bodies, breccia pipes, and east-west trending fissure veins which do not have an equal counterpart in the San Manuel area across the San Pedro Valley to the southwest. The San Manuel - Kalamazoo copper deposits are localized by a monzonite porphyry stock and comagmatic dikes which trend ENE across older Precambrian Oracle Granite (Creasey, 1967; Lowell, 1968). There appears to be a several-mile separation between the Copper Creek and San Manuel segments along the San Pedro Valley, which probably resulted from mid-Tertiary Basin and Range tectonism.

Viewed on a regional scale, the eastern continuation of the Copper Creek - San Manuel belt may well extend to the Safford and Morenci districts where similar ENE trending Laramide-age intrusive rocks and alteration zones are recognized (Robinson and Cook, 1966; Moolik and Durek, 1966). To the west, the belt may extend past the Owl Head mining district where a few east trending fissure veins and a small quartz diorite stock of possible Laramide age are exposed (Barter; 1962; Iles, 1967). Much of the area beyong the Owl Head district is underlain by Quaternary gravel and alluvium.

SILVER BELL DISTRICT

Superimposed upon a northwest trending zone of several hydrothermally altered intrusive rocks ("major structure") is a closely spaced system of northeast to east trending mineralized fissures and veinlets that control the mineralization at Silver Bell. Several east trending porphyry dikes follow the fissure vein trend for a few miles beyond the limits of mineralization to the east (Watson, 1964, 1968). The mineralized fissures do not continue for any great distance to the west.

The Lakeshore deposit is about 23 miles west-northwest of Silver Bell and may constitute a continuation of the northwest trending "major structure" at Silver Bell. Whether or not the Lakeshore deposit is similarly controlled by an east trending fissure vein system has to be verified by future geological investigations.

The Amole pluton (73-75 m.y.) in the northern part of the Tucson Mountains and the comagmatic easterly trending Silver Lily dike swarm (Mayo, 1966) testify for a Laramide intrusive cycle with little associated mineralization. The orientation of the dikes, however, is similar to the Laramide hypabyssal rocks in the productive districts described above, suggesting that the emplacement of the Silver Lily dikes was also influenced by a similar tectonic stress pattern.

DISCUSSION

The systematic ENE to east trending Laramide intrusive and mineralized fracture pattern in south central Arizona represents a fundamental zone of weakness that was activated during the Laramide magmatic cycle and which served as primary structural control for the emplacement of porphyry copper deposits and accompanying hydrothermal alteration.

Many attempts have been made in the past to relate the distribution of mineral deposits to some recognizable structural framework, be it on a local or regional scale. Important contributions to this problem include works by Butler (1929, 1933), Billingsley and Locke (1935, 1941), Mayo (1959), Wisser (1960), Schmitt (1959, 1966), Damon and Mauger (1966), Guilbert and Sumner (1968), Heidrick and Rehrig (1969), and Titley (1970), just to mention a few.

The predominant Laramide direction shown in Figure 1 agrees well with the results obtained by Heidrick and Rehrig (1969), but it neither conforms strictly with the N 70°W trending Texas zone, as defined by Ransome (1915), and outlined by Guilbert and Sumner (1968), nor with the N 20-40°E trending mineral belts presented by Landwehr (1967). Furthermore, the presently defined mineral belts bear no similarity whatever to the confusing pattern developed by Wertz (1970).

The northeast trending Globe belt of Landwehr includes much of the area in Figure 1 and extends from Ajo past Silver Bell, Ray, Superior, Globe-Miami, to northwest New Mexico. Aside from the apparent alignment of these various mineral deposits, there is no indication from local geological data that <u>all</u> of these mentioned localities are connected by one major structure.

Schmitt (1959) includes all mineral deposits of southeast Arizona into his N 45°E trending Precambrian orogenic belt which generally follows the older Precambrian foliation direction. The present study has shown that the Precambrian fabric indeed exerts a strong local control on the emplacement of the Laramide structures (Kelvin-Ray-Globe area), but that the regional control is a unique Laramide feature. In his later paper (1966, Fig. 2), Schmitt attributes considerable importance to the intersection of the major north trending Wasatch-Jerome orogen with the Texas lineament for the localization of the main porphyry copper deposits in Arizona.

An interesting approach has recently been taken by Titley (1970) in relating Laramide-age base metal deposits to the margins of the Cretaceous Sonoran embayment in southeast Arizona.

PRESENT INTERPRETATION

The intrusive and mineralization pattern described in this paper reflects regional NNW-SSE directed extension resulting either from horizontal east-west compression, from a NE-SW directed regional shear couple, or from the formation of several east-west elongated domal uplifts with accompanying longitudinal tension fractures.

Tension fractures can form parallel to the maximum stress direction in a region subjected to lateral compression. Very little evidence, however, exists in the studied area for this type of Laramide deformation judging from the lack of folding and thrusting in the younger Precambrian, Paleozoic, and Mesozoic sedimentary strata. Thus, north-south extension is probably not related to east-west compression in this case.

It is also unlikely that a regional shear couple caused the east-west tension zone because the resulting pattern would be an en echelon arrangement rather than a continuous belt that can be followed for tens of miles along strike.

The third alternative involves regional elongated upwarping which is, in the writer's opinion, an attractive concept to explain the distribution and orientation of Laramide intrusive rocks. The required doming is gentle enough to prevent any visible warping in the overlying sedimentary strata. Scale model experiments by Cloos (1939) and Beloussov (1960, 1961) demonstrated that subparallel extension fractures will develop along the crest of an uplifted elongated domal feature. According to Cloos, the amount of uplift is minimal for the first appearance of longitudinal tension fractures. In the case of a 30-mile wide updomed area, only about 500 feet of uplift is required to form longitudinal fractures. The inclination of the dome flanks is less than $1/2^{\circ}$, which for all practical purposes is unrecognizable.

The longitudinal tension fractures are the deeply penetrating avenues that guided the ascending mineralizing solutions and controlled the passive emplacement of the Laramide hypabyssal rocks and elongated stocks. It is very likely that one is not dealing here with a single domal uplift, but with several subparallel elongated swells which localized the various dike swarms. Assuming that no assimilation of crustal material took place, the Laramide intrusive pattern in the Tortilla Mountains indicates about 14% north-south extension of the crust during the Laramide orogeny.

Uplift and large scale doming with the concomitant formation of longitudinal tension fractures controlling the emplacement of igneous rocks and mineralizing fluids are, in the writer's opinion, plausible mechanisms to explain the Laramide intrusive and mineralization pattern as depicted in Figure 1. The recognition of these belts is considered a valuable exploration tool in the search for additional base metal deposits, especially where they project into adjacent pediment areas.

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