Extension of Laramide magmatism in southwestern North America into Trans-Pecos Texas

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ABSTRACT

The Red Hills intrusion hosts the easternmost porphyry copper-molybdenum system in southwestern North America and consists of quartz-sulfide stockwork veins in sericitized porphyritic quartz monzonite. Zircon U-Pb and molybdenite Re-Os analyses yield ages of 64.2 ± 0.2 Ma and 60.2 ± 0.3 Ma, respectively, indicating that the Red Hills intrusion and mineralization are distinctly older than all other Tertiary magmatism (48–17 Ma) in the Trans-Pecos region of Texas, including the nearby 32 Ma Chinati Mountains caldera. The Red Hills intrusive system is contemporaneous with and genetically related to other Laramide magmatic systems (75–54 Ma) that host porphyry copper deposits in Arizona, southwestern New Mexico, and northern Mexico. These results significantly extend the Laramide magmatic province eastward and suggest that Laramide subduction-related magmatism and deformation are coextensive over a broad area of southwestern North America.

Keywords: porphyry, copper, Laramide, Trans-Pecos, magmatism, Texas.

INTRODUCTION

Porphyry copper deposits are the principal commercial source of copper and an important source of molybdenum and other metals. The formation of these deposits is related to the intrusion of subduction-related magmas at shallow levels of Earth's crust where associated hydrothermal systems deposit copper- and molybdenum-bearing minerals in stockwork fractures (Titley and Heidrick, 1978; Titley and Beane, 1981; Lang and Titley, 1998).

Porphyry copper deposits in southwestern North America cluster in southern Arizona, southwestern New Mexico, and northern Mexico and are largely related to Laramide (75–54 Ma) magmatism (Fig. 1). The Red Hills porphyry copper-molybdenum system in west Texas is located ~300 km east of the closest Laramide porphyry copper deposit.

The Red Hills deposit lies ~1 km south of the structural margin of the Chinati Mountains caldera, a major volcanic center dated at 32 Ma (Fig. 2). Price and Henry (1982) postulated that the Red Hills intrusion was genetically related to the Chinati Mountains caldera, on the basis of the presence of altered porphyry present in the basal agglomerate derived from the caldera wall. However, Henry et al. (1986) reported a K-Ar age for sericite from the Red Hills stockwork of 56 ± 1.4 Ma, which was discounted as being too old to be correct.

Field mapping (Gilmer, 2001), supported by U-Pb zircon, Re-Os molybdenite, and $^{40}Ar/^{39}Ar$ sericite geochronological studies, indicates that the Red Hills magmatic-hydrothermal system is not related to the Chinati Mountains caldera. Instead, these results demonstrate that components of the Laramide magmatic arc extend as far east as deformation associated with Laramide subduction in Trans-Pecos Texas (i.e., the Laramide front; Fig. 1). This study indicates that Red Hills represents an eastward extension of Laramide subduction-related magmatism that formed the major porphyry copper province of southwestern North America.

GEOLOGIC SETTING OF THE RED HILLS PORPHYRY SYSTEM

The Red Hills porphyry copper-molybdenum deposit is located in the Trans-Pecos region of Texas, 8 km west of Shafter in Presidio County (Ross, 1943; Head, 2002; Fig. 2). It consists of a quartz monzonite porphyry stock that has intruded Permian limestones, sandstones, and siltstones, creating peripheral hornfels and skarn bodies enriched in zinc, lead, and silver (Price and Henry, 1982). The Red Hills porphyry deposit consists of an open-pit resource of >18 Mt at a grade of 0.35% copper and 0.07% molybdenum (Silver, 1999).

Cordilleran magmatism in west Texas produced great volumes of volcanic and intrusive rock between 38 and 31 Ma. Magmas were related to subduction off western North America (Henry et al., 1991; Price et al., 1987). A number of calderas in the region, including the Chinati Mountains caldera, produced differentiated alkali-calcic to alkalic suites in the form of ash-flow tuffs, intracaldera lava flows, and intrusions. Cepeda and Henry (1983) suggested that most hydrothermal mineralization in the region (including Red Hills) was related to the 38–31 Ma calderas.

The Red Hills porphyry system lies within the boundary area between the intensely deformed Chihuahua tectonic belt to the west and the relatively stable Diablo platform to the east. Within the Chihuahua tectonic belt, Cretaceous rocks were folded, overturned, and cut by thrust faults during Late Cretaceous–early Tertiary (Laramide) deformation (Gries and Haeggni, 1971). The corresponding rocks are flat lying on the Diablo platform. Cretaceous and Permian rocks south of the Chinati Mountains are locally tilted and thrust faulted. The outward dip of strata away from the Chinati Mountains caldera is interpreted to have resulted from caldera development (Ross, 1943; Rix, 1953).

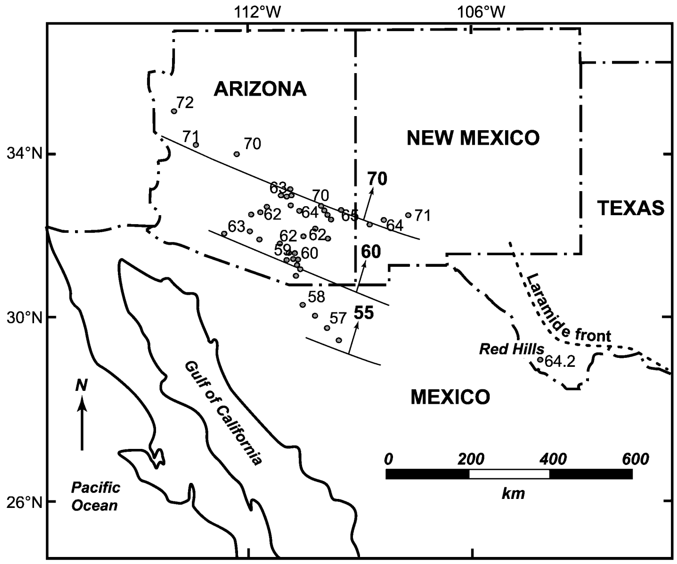

Figure 1. Age distribution (Ma) of porphyry copper deposits in southwestern North America. Modified after Titley (1993); Laramide deformation front from Muehlberger (1980).

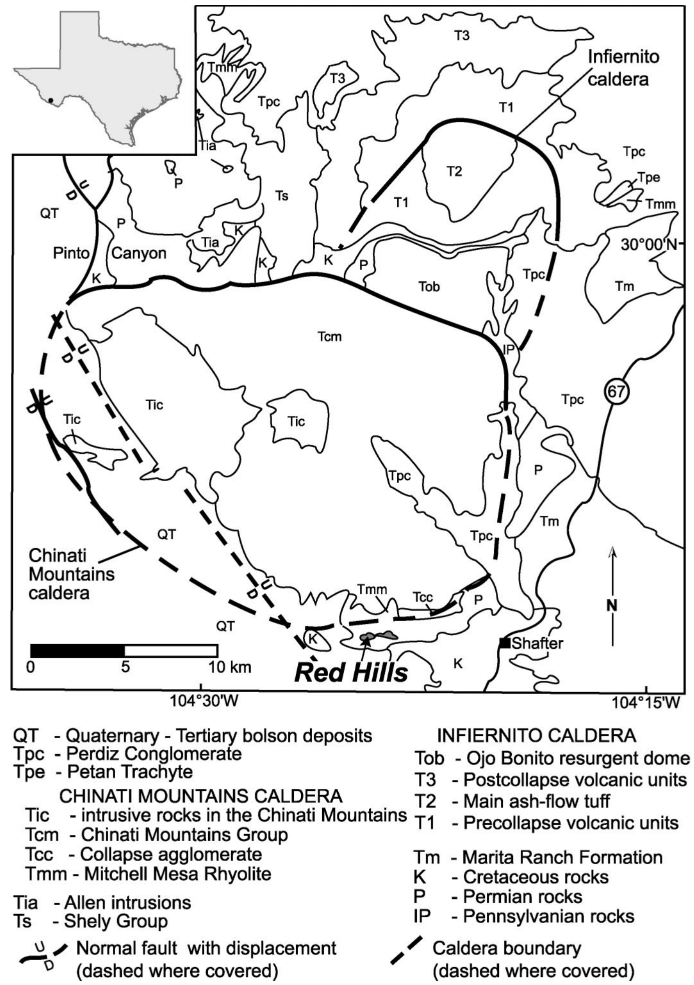

Figure 2. Location of Red Hills porphyry copper deposit, relative to Chinati Mountains caldera. Modified from Cepeda and Henry (1983).

NEW FIELD DATA

Geologic mapping and drill hole data have revealed two parts to the Red Hills intrusive system (Gilmer, 2001; Fig. 3). The western part of the intrusion shows extensive alteration and mineralization, whereas the eastern part is less altered and lacks sulfide mineral concentrations. The two parts of the intrusion have been traced to within 35 m of each other and are inferred to be contiguous beneath alluvial cover.

Extensive hydrothermal alteration differentiates the part of the intrusion that constitutes the Red Hills porphyry copper-molybdenum deposit from the less altered part. The intrusion underwent potassic alteration that was overprinted by extensive quartz-sericite-pyrite (phyllic) and argillic alteration; zones of intense silicification locally occur in the intrusion. Hypogene mineralization extends to the surface in many areas with local areas of secondary enrichment. A leached cap with oxidized iron sulfides accounts for the distinct reddish exposures that give Red Hills its name.

The unaltered intrusion is predominately quartz monzonite with minor quartz latite inclusions and associated dikes. The quartz monzonite is porphyritic with a fine-grained groundmass of predominately quartz and plagioclase. Subhedral quartz, alkali feldspar, and plagioclase are the most abundant phenocrysts present. The fact that even in the least altered parts of the intrusion, chlorite and epidote coexist and replace mafic phases suggests some degree of hydrothermal alteration.

Dikes of quartz monzonite and quartz latite are common in the sedimentary wall rocks but absent in the intrusion (Fig. 3). These dikes are up to 10 m wide and are generally parallel to the local structure. The mineral assemblage of these dikes is consistent with that of the main body of the Red Hills intrusion; the dikes have microphenocrysts of quartz and plagioclase (up to 5 mm). Zones of intense silicification are present along local east-trending faults and within the intrusion, extending as much as 5 m into wall rocks. Roof pendants of Permian strata within the intrusion suggest shallow emplacement of the Red Hills magma. Alteration of the roof pendants is very similar to that of the adjacent skarn bodies. The stratigraphic cover above the Red Hills system has been estimated to be approximately 2 km at the time of emplacement based on fluid inclusion studies (Gilmer, 2001).

Many of the faults observed in the study area (Fig. 3) appear to postdate the intrusion of the Red Hills porphyry and show local dip-slip offset. The overall east-west orientation of the faults is similar to that of the joints and veins measured in the Red Hills stockwork; this parallelism indicates that they formed in the same stress regime (Gilmer, 2001). Intense silicification along the southeastern fault within the intrusion suggests that these faults are roughly contemporaneous with the intrusion as circulating hydrothermal fluids would be necessary for silicification.

ISOTOPIC DATING

To establish a precise age for the Red Hills intrusion and evaluate the chronological relationship to the 32 Ma Chinati Mountains caldera, samples were selected to determine both the age of crystallization for the Red Hills intrusion and the age of intrusion-hosted mineralization (Gilmer, 2001)[1].

U-Pb Age Results

Samples of quartz monzonite, showing phyllic alteration, from the Red Hills intrusion yielded subhedral to euhedral 80–160 μm zircons for U-Pb geochronology. All zircon fractions were abraded prior to analysis. U-Pb isotopic data from four fractions of igneous zircons, having masses of 0.0034–0.0188 mg, are presented in Gilmer (2001). These points define a line corresponding to an age of 64.2 ± 0.2 Ma (Fig. 4). A near-ideal mean weighted standard deviation of 0.93 indicates that this isotopic system was undisturbed.

[1]GSA Data Repository item 2003059, U-Pb, Re-Os, sericite age-dating methods and results, is available from Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301, editing@geosociety.org, or at www.geosociety.org/pubs/ft2003.htm.

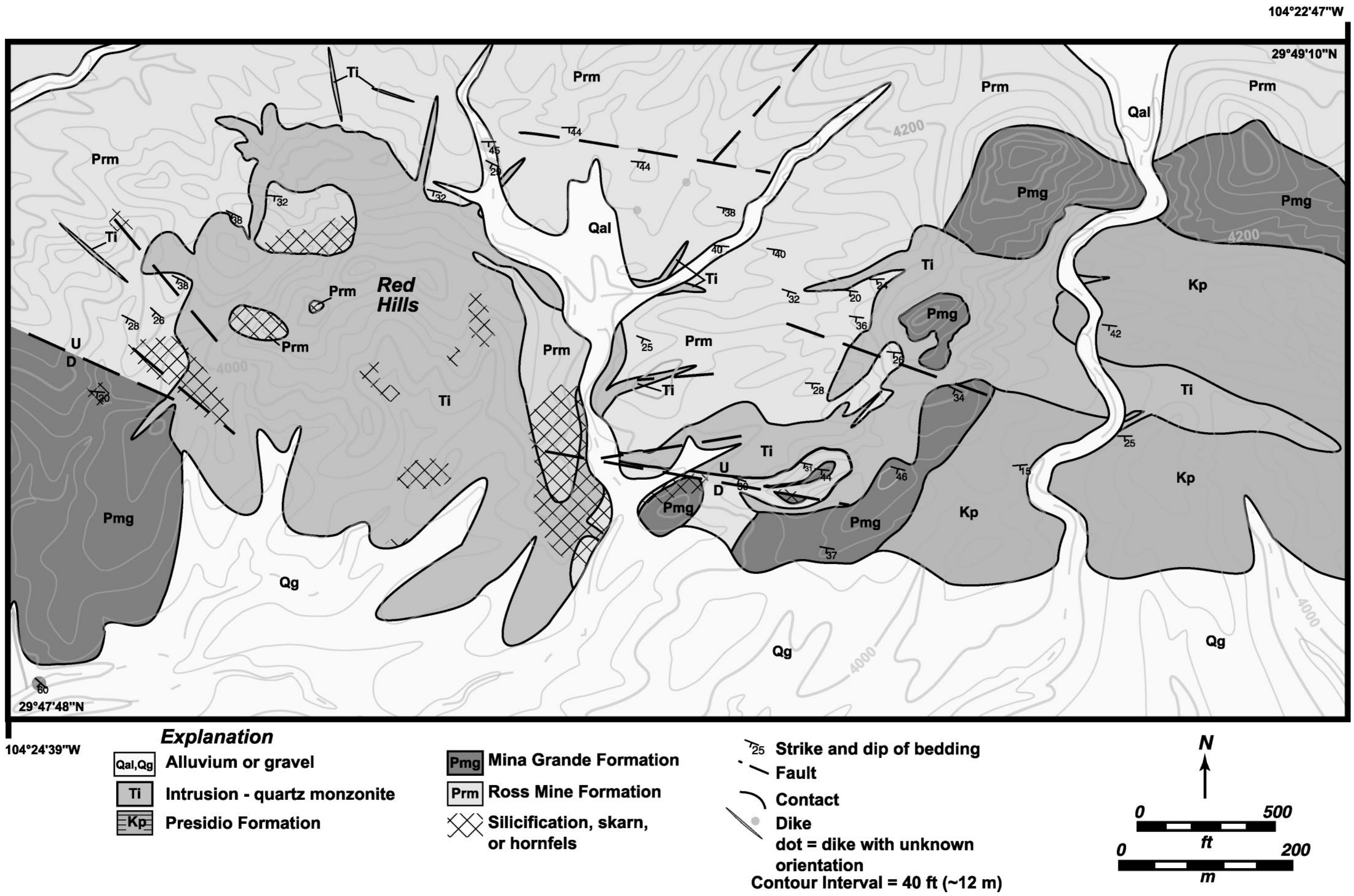

Figure 3. Bedrock geology of Red Hills area, Presidio County, Texas. Modified after Gilmer (2001).

Re-Os Age Results

The Re-Os system is a particularly useful method for dating hydrothermal molybdenum-bearing deposits because it enables direct dating of the mineralizing event rather than inferring the mineralization age from alteration products (Stein et al., 1998). Samples of Red Hills quartz monzonite showing phyllic alteration yielded fine-grained anhedral molybdenite. One fraction (11 mg) was dated by using a decay constant of 1.66×10^{-11} yr^{-1} and yielded an age of 60.2 ± 0.3 Ma (Gilmer, 2001). The fraction analyzed contained 234 ppm total Re and 125.75 ppb ^{187}Os. The age of mineralization was calculated by assuming no initial radiogenic Os, and the errors were calculated according to the method described by Mathur et al. (2002).

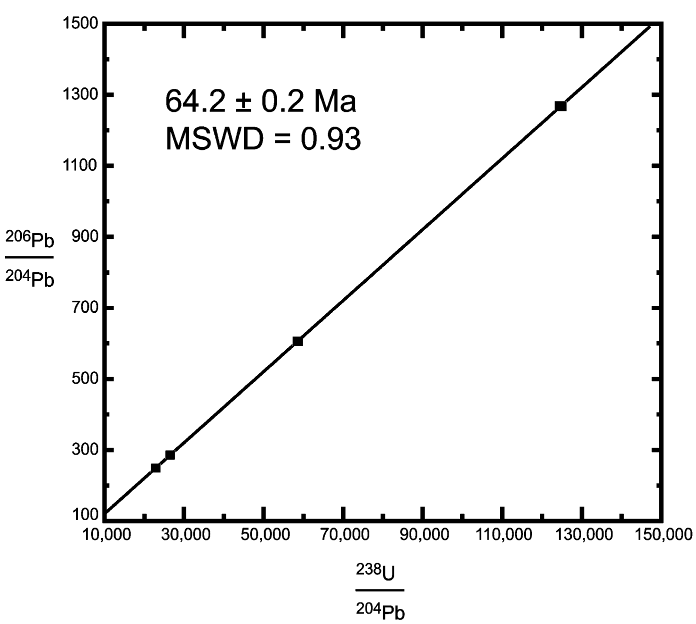

Figure 4. $^{206}Pb/^{204}Pb$ vs. $^{238}U/^{204}Pb$ isochron of zircons; analyses at University of Texas at Austin. MSWD—mean square of weighted deviates.

$^{40}Ar/^{39}Ar$ Age Results

The sericite separate that had previously yielded a K-Ar age of 56.6 ± 1.4 Ma (Henry et al., 1986) was repurified and analyzed by $^{40}Ar/^{39}Ar$ step-heating in a resistance furnace. The sample did not yield a plateau, but the data are consistent with an age of ca. 61 Ma (Fig. 5). The first ~10% of released Ar gave highly variable ages that suggest either alteration or reheating, consistent with possible reheating from caldera-related magmatism at 32 Ma. Subsequent steps decreased progressively from ca. 66–60 Ma. Best age estimates are either a weighted mean of the high-temperature steps (61.58 ± 0.34 Ma) or an isochron of the same steps (60.83 ± 0.79 Ma).

DISCUSSION

The U-Pb zircon age (crystallization age) of 64.2 ± 0.2 Ma, the slightly younger Re-Os molybdenite age of 60.2 ± 0.3 Ma, and the $^{40}Ar/^{39}Ar$ sericite age (hydrothermal mineralization age) of ca. 61 Ma clearly indicate that the Red Hills intrusion and associated mineralization are not temporally associated with the extensive middle Tertiary caldera-related magmatism in Trans-Pecos Texas. However, an apparent difference of 4 m.y. is indicated between the age of Red Hills magma

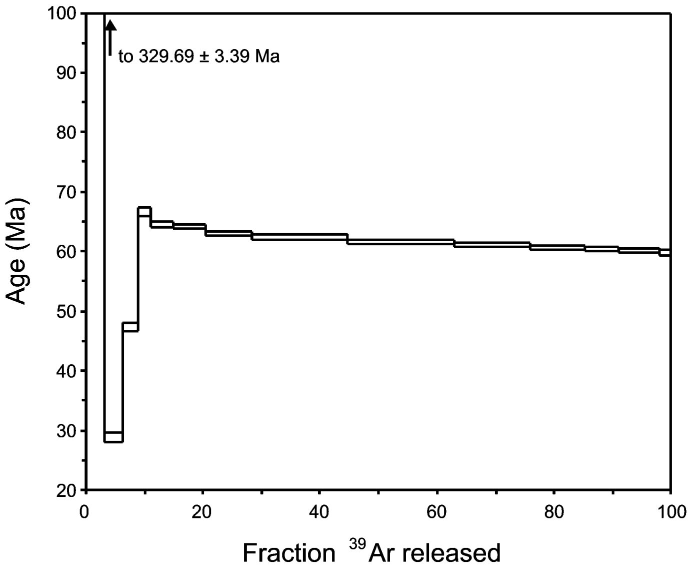

Figure 5. ^{40}Ar/^{40}Ar step-heating results for sericite sample 81-319; analyses at University of Nevada at Las Vegas.

crystallization and the age of intrusion-hosted mineralization. This discrepancy could be due to differences in analytical methods or could have a geologic explanation whereby a larger and younger igneous body at depth is responsible for mineralization that is younger than the host Red Hills intrusion. Because the analytical methods are dating different processes, existing information does not allow a choice between these two possibilities.

Regardless, the ages provide considerable constraints on the timing of crystallization and mineralization and, combined with new field data, confirm that the Red Hills magmatism was not temporally related to the nearby 32 Ma Chinati Mountains caldera. Documentation of Tertiary magmatism in Trans-Pecos Texas previously has been restricted to between 48 and 17 Ma (Henry et al., 1986). On the basis of the new ages, the Red Hills intrusion is ~15 m.y. older than this range and >30 m.y. older than the nearby Chinati Mountains caldera. Thus, the Red Hills intrusion is the oldest-known Tertiary igneous rock in west Texas. The collocation of different-aged igneous systems can be explained by the variable dip and depth of the subducting slab beneath North America between 80 and 20 Ma.

The Laramide age for the Red Hills porphyry falls within the range of the porphyry copper systems (75–58 Ma) in Arizona, New Mexico, and northern Mexico. The Red Hills porphyry fits well with age trends presented by Titley (1993) (Fig. 1). Red Hills represents a significant eastward extension of Laramide subduction-related magmatism.

CONCLUSIONS

New field work and geochronology show that the Red Hills porphyry copper deposit is not related to the nearby 32 Ma Chinati Mountains caldera (Fig. 2). The 64 Ma age of the Red Hills intrusion corresponds to the Laramide age of formation for other porphyry copper systems in southwestern North America. The new ages indicate that the Red Hills intrusion is not only the oldest Tertiary igneous body in Trans-Pecos Texas, but these results significantly extend the Laramide magmatic province eastward in southwestern North America to coincide with the extent of Laramide deformation. These results further suggest that there is a significantly larger region for the exploration of these important ore deposits than the current cluster of producing deposits.

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