Mid-Tertiary arcuate dikes and faults of the Rio Hondo-Red River drainages, Sangre de Cristo Mountains, New Mexico: A postulated outlying ring-fracture zone to the Miocene Questa caldera

David M. Jones, 1990, pp. 365-368

in:

Tectonic Development of the Southern Sangre de Cristo Mountains, New Mexico, Bauer, P. W.; Lucas, S. G.; Mawer, C. K.; McIntosh, W. C.; [eds.], New Mexico Geological Society 41st Annual Fall Field Conference Guidebook, 450 p.

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MID-TERTIARY ARCUATE DIKES AND FAULTS OF THE RIO HONDO–RED RIVER DRAINAGES, SANGRE DE CRISTO MOUNTAINS, NEW MEXICO: A POSTULATED OUTLYING RING-FRACTURE ZONE TO THE MIOCENE QUESTA CALDERA

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Abstract—Arcuate faults, dikes and the distribution of base and precious metals occurrences along the Red River and Rio Hondo drainages of northern New Mexico define an integrated mid-Tertiary structural break. This break represents a ring-fracture zone which exhibits normal displacement down to the north in the direction of the 26 Ma Questa caldera; movement along the fault zone is bracketed between 26–21 Ma. The ring-fracture zone defines a previously unidentified outlying structural boundary to the Questa caldera.

INTRODUCTION

One of the most prominent circular geomorphic features in northern New Mexico is located in the Sangre de Cristo Mountains, centered roughly 29 km north-northeast of the town Taos (Fig. 1). Readily visible on 1:1,000,000 scale aerial photographs, this circular feature is defined by the upper reaches of the Red River, Rio Hondo and Columbine drainages. Previous workers named this feature the Red River ring structure (Clark, 1966; Carpenter, 1968) and interpreted it as the product of intersecting fault systems. They further noted that Tertiary intrusions were preferentially located along the outside edge of the ring structure. Recent published works (Lipman, 1983; Lipman and Reed, 1989) ascribe its origin to intersecting orthogonal fault sets.

This paper presents a revised analysis of the ring structure based on unpublished field mapping conducted by the author in 1982–83. The study evolved from an evaluation of molybdenum mineralization along the South Fork, and other branches, of the Rio Hondo drainage system (Jones and Norris, 1984). The unpublished data document mid-Tertiary arcuate dikes and faults along the Rio Hondo drainage which, together with previously identified structural features, define an elliptical ring-fracture zone roughly 20 km in diameter. The eastern half of this feature roughly coincides with the Red River ring structure; the western half was not previously identified. The southern margin of the 26 Ma Questa caldera (Lipman, 1983) bounds the ring structure to the north (Fig. 2). The integrated features which define the ellipse are here interpreted as a ring-fracture zone related to the development of the Questa caldera. The fracture zone likely formed concurrently with caldera collapse and/or during resurgent magmatic uplift.

Base and precious metal prospects are common along, and are localized by, the arcuate structural zone. Variations in relative metal abundances along the zone may reflect a regional metal zoning, possibly related to current depth of exposure.

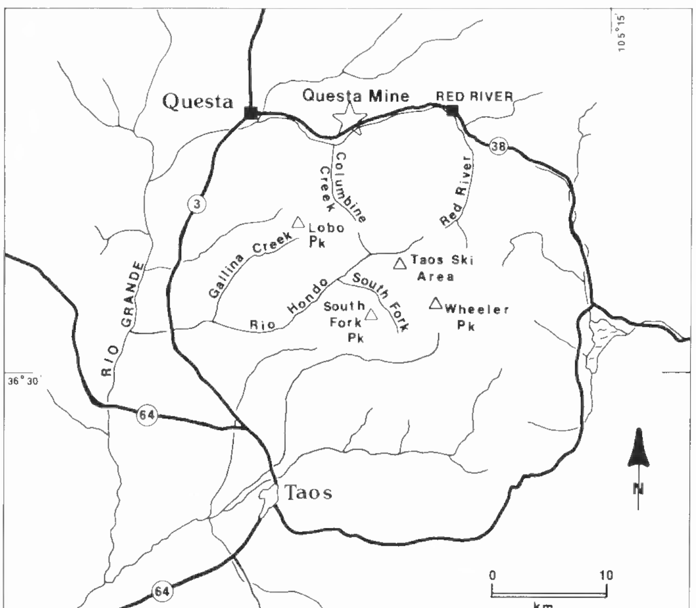

FIGURE 1. Location map for the Rio Hondo and Red River drainages.

GEOLOGIC SETTING

The Rio Hondo drainage dissects the western slope of the Sangre de Cristo Mountains, running roughly 30 km from its head near Taos Ski Area to its confluence with the Rio Grande (Fig. 1). A simplified geologic map of the Rio Hondo drainage and surrounding areas, structure omitted, is shown in Figure 2. Proterozoic metaigneous and metasedimentary rocks constitute the only volumetrically significant pre-Tertiary lithologies in the region (Reed, 1984). These rocks have been intruded by at least two mid-Tertiary plutons (Fig. 2): the Rio Hondo

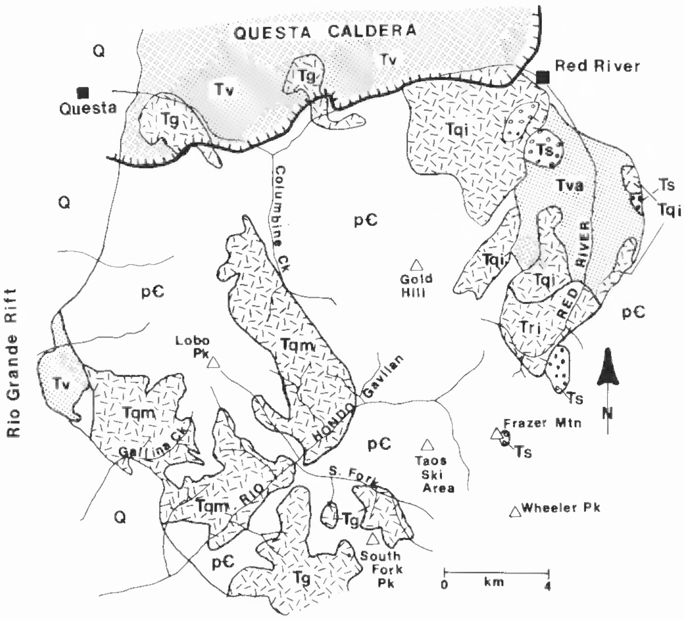

FIGURE 2. Simplified lithologic map of the Rio Hondo and Red River drainages. pЄ = Proterozoic rocks, undivided; Tv = Oligocene to Miocene volcanic rocks, undivided; Tva = dominantly Oligocene andesites; Tqi = intrusive(?) quartz latite; Tqm = Rio Hondo quartz monzonite to granite; Tg = high-silica biotite granite; Tg south of Rio Hondo is the Lucero granite; Tri = Relica Peak rhyolite; Ts = Miocene sedimentary rocks (geology after Clark and Read, 1972; Lipman and Reed, 1989; Jones, unpubl., 1981–84).

quartz monzonite (26–25 Ma) and the Lucero granite (21 Ma; Lipman et al., 1986). These plutons constitute the southernmost extent of regional magmatism associated with the development of the 26 Ma Questa caldera (Lipman, 1983). Recent age date studies (Czamanske et al., 1990) attribute a younger age to Rio Hondo pluton, but, as addressed below, this is interpreted as a reset age.

The southern margin of the Questa caldera is the structural host to the numerous molybdenum orebodies at Questa (Leonardson et al., 1982) which are currently being mined after a three-year hiatus. Molybdenum ore is closely associated with 24–23 Ma (Laughlin et al., 1969; Czamanske et al., 1990) high-silica granites (74–76% SiO_2). Molybdenum mineralization along the South Fork of the Rio Hondo is associated with granites of nearly similar composition (Jones, unpubl., 1981; Lipman, 1983).

NATURE OF THE RING-FRACTURE ZONE

The ring-fracture zone, as here defined, is discussed in three segments. The first segment begins near the town of Red River and follows the Red River drainage south to its head north of Frazer Mountain (Fig. 2). The second segment trends west from Frazer Mountain across the slopes of the Taos Ski Area and into the South Fork drainage of the Rio Hondo. The third segment trends west from South Fork, crosses the Rio Hondo and continues to the mouth of Gallina Creek (Fig. 2). Together, these three segments define roughly 180° of arc.

The geologic elements which define the ring-fracture zone include: (1) an arcuate fault zone marking significant structural and lithologic discontinuities; (2) Tertiary igneous rocks which have intruded the fault zone; and (3) the common occurrence of Tertiary base and precious metals mineralization and alteration along the fault zone.

Red River to Frazer Mountain

From its head near Frazer Mountain, the Red River flows nearly due north to the town of Red River, where it bends sharply westward (Fig. 2). This segment of the river follows, and lies just west of, an arcuate fault zone (Fig. 3). This fault separates topographically high Precambrian rocks on the east from Oligocene andesite flows and quartz latite intrusions(?) at lower elevations to the west (Clark and Read, 1972; Lipman and Reed, 1989). The displacement across this fault is at least several hundred meters down to the west, and has been estimated to be greater than 1000 m (Lipman and Reed, 1989, cross section D–D′).

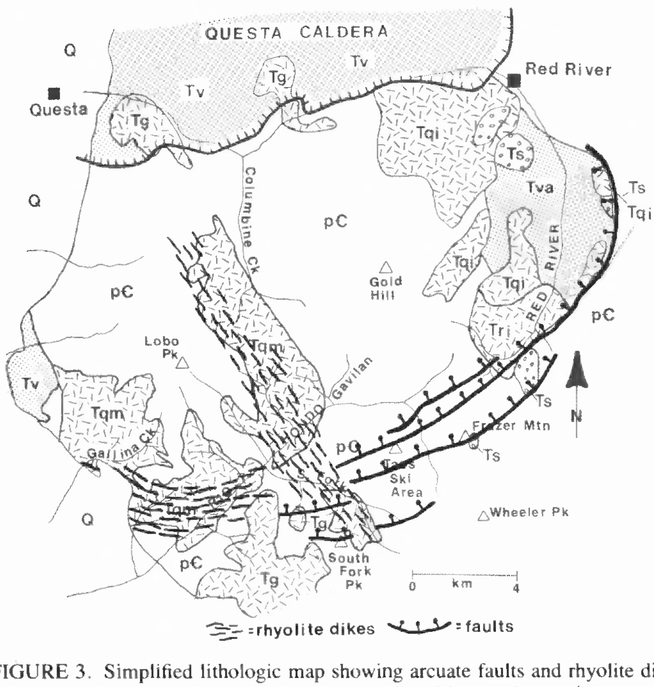

FIGURE 3. Simplified lithologic map showing arcuate faults and rhyolite dike swarms (schematic) along the Rio Hondo and Red River drainages (data source same as Figure 2).

Poorly consolidated Miocene sedimentary rocks are preserved in greater abundance along the fault and within the downdropped area (Fig. 2) than to the east of the fault (Clark and Read, 1972; Lipman and Reed, 1989).

Near its head, the Red River and the the fault zone coincide; here, the river cuts through a large mid-Tertiary felsic intrusion known as the rhyolite of Relica Peak (Fig. 2). The Relica Peak rhyolite intruded, and is locally bounded on the southeast by, the fault zone (Fig. 3; Clark and Read, 1972; Lipman and Reed, 1989). Along the trace of the fault zone so far discussed the strike changes from northwest, to north, to northeast.

Frazer Mountain to South Fork

The fault zone which localized the emplacement of the Relica Peak rhyolite trends southwest across the northern slope of Frazer Mountain (Fig. 3). This ridge crossing marks the high divide which separates the Red River and Rio Hondo drainages. The fault zone continues west-southwest across the upper slopes of the Taos Ski Area and then descends into the South Fork where the drainage runs nearly east-west. The character of the fault along this segment is that of a shear zone, where the presence of gneisses and schists allowed dominantly ductile versus brittle failure of the rocks. The shear zone typically dips to the north at 60–85°, but locally dips steeply to the south.

Along this segment the fault demarcates contacts between various Precambrian lithologies (Lipman and Reed, 1989). This shear zone is the most prominent structure of a series of previously unmapped arcuate faults which extend from upper Red River to the South Fork (Fig. 3). Many segments of these faults are intruded by mafic to felsic dikes of Tertiary age (Restrepo, 1972; Jones, unpubl., 1983). These subsidiary faults also controlled the emplacement of the larger Tertiary granite stock along South Fork (Jones and Norris, unpubl., 1982). Most of these faults and intrusive bodies dip to the north at 60–90°.

Clark and Read (1972, p. 93) postulated that the east-northeast fault zone represents an exposed segment of the Jemez lineament, an inferred major cratonic basement structure which extends from Springerville, Arizona to the Valles caldera, New Mexico. Recent work (Reed, 1984), however, reveals that the northeast-trending structure is discontinuous southwest of South Fork.

Displacement across this segment of the fault zone is down to the west and north, similar in sense of throw to the Red River–Frazer Mountain segment. Evidence for this is found in: (1) drag folds north of Frazer Mountain (Restrepo, 1972; Jones, unpubl., 1983); (2) juxtapositions of metamorphic rocks of differing metamorphic grades (Restrepo, 1972; Reed, 1984); and (3) the preservation of Tertiary sediments on the north side of a fault just east of the summit of Frazer Mountain (Fig. 3; Jones, unpubl., 1983). In addition, Precambrian foliations are notably discontinuous across these faults at many locations (J. Reed, oral commun., 1984; Jones and Norris, unpubl., 1982). The strike of this segment of the fault zone changes continuously from northeast, near Frazer Mountain, to nearly east-west along South Fork.

South Fork to Gallina Creek

The third segment of the ring-fracture zone is marked by arcuate dikes and faults which extend from near the mouth of South Fork to the mouth of Gallina Creek (Fig. 3). The dikes and faults crosscut the Rio Hondo pluton in an arcuate manner (Fig. 4; faults not shown). The dikes strike east-northeast to west-northwest and dip northerly at 55–80°. The dike swarm intruded a highly sheeted fault zone. Brittle faults are common between the dikes and also peripheral to the dike swarm.

The vast majority of dikes are porphyritic rhyolites containing phenocrysts of quartz and alkali feldspar; they are commonly flow banded along their margins. These rhyolites range in thickness from <1 m to >20 m (average ~9 m). Slightly older dikes, crosscut by the rhyolites, are quartz latitic in composition, with sparse quartz and relatively abundant plagioclase phenocrysts; these dikes are generally <5 m in thickness. Mafic dikes, of probable lamprophyre affinity, are less common and generally do not exceed 1 m in thickness. The easternmost mapped dike of the east-west-trending swarm crops out in a roadcut at the South Fork Rio Hondo confluence (Fig. 4). Complicating the structural picture

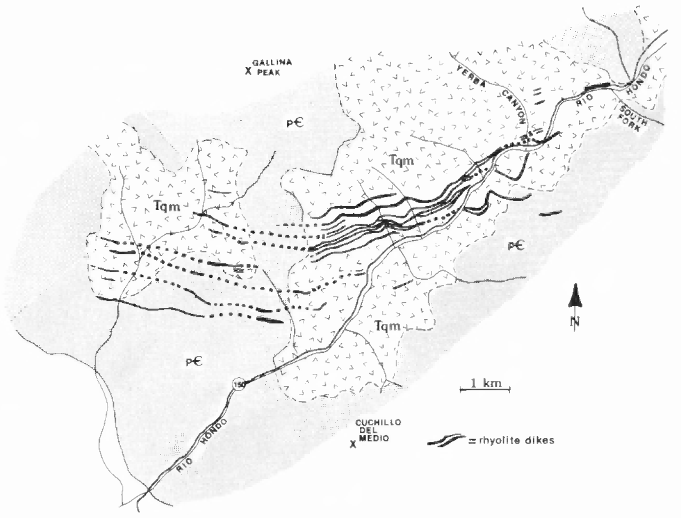

FIGURE 4. Map of a portion of the rhyolite dike swarm along the Rio Hondo drainage (geology after Jones, unpubl., 1984).

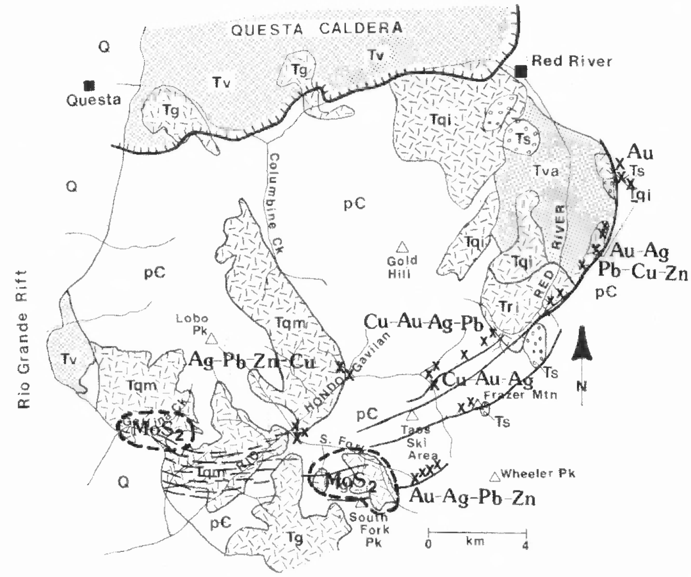

FIGURE 5. Prospect locations and metal occurrences along the upper Red River and Rio Hondo drainages (data from Lindgren et al., 1910; Park and McKinlay, 1948; Schilling, 1960; Jones and Norris, 1984).

is a massive north-northwest-trending rhyolite and quartz latite dike swarm which lies between South Fork and Gavilan Canyon (Fig. 3). This linear dike swarm marks the western terminus of the Red River to South Fork shear zones and the eastern terminus of the arcuate dike swarm. Lack of exposure near the mouth of South Fork obscures possible interrelations between these features.

Czamanske et al. (1990) estimate an emplacement age of 21.2 ± 0.1 Ma ($^{40}Ar/^{39}Ar$) for the Rio Hondo pluton, significantly younger than that inferred from earlier studies (Lipman et al., 1986). However, two of the samples for which younger dates were obtained occur close to (#Q83J59) or between (#Q84J6) demonstrably younger intrusive bodies. As the authors themselves acknowledge, "the measured ages are open to interpretation based on thermal history" (Czamanske et al., 1990). The numerous felsic intrusions, and associated alteration halos, which crosscut the Rio Hondo pluton are clear evidence for a protracted thermal history. On this basis, the inferred emplacement age of 26–25 Ma (Lipman et al., 1986) is here accepted as correct.

Base and precious metals mineralization

From upper Red River to the mouth of Gallina Creek, the ring-fracture zone has been heavily prospected for base and precious metals (Fig. 5). Little significant production is reported for any of the old workings (Lindgren et al., 1910; Park and McKinlay, 1948; Schilling, 1960). Although overshadowed by the dominance of the Questa deposits to the north, this nearly continuous string of metal occurrences probably represents an integrated mid-Tertiary hydrothermal system which exhibits regional zoning of metals. From Red River to just east of South Fork, the old mines and prospects are enriched in precious and base metals (Fig. 5). From South Fork west to Gallina Creek molybdenum mineralization and associated alteration is the dominant form of metal deposition.

From upper Red River to the upper Rio Hondo the more significant prospects include the Black Copper mine (Au-Ag-Pb-Zn-Cu), the Silver Star (Ag-Pb-Cu), the Comstock (Cu), the Highline ("Bull of the Woods"; Cu, trace Au-Ag-Pb), and the Frazer (Cu-Au-Ag) (Lindgren et al., 1910; Park and McKinlay, 1948; Schilling, 1960; Restrepo, 1972). With the exception of the Silver Star, all of these prospects lie along the fault zone shown in Figure 5. The listed prospects are all quartz-sulfide or oxide-vein deposits which both follow and crosscut Precambrian foliations. Although typically hosted entirely within Precambrian rocks they are easily distinguished as distinct from the Proterozoic volcanogenic deposits south of Gold Hill (Restrepo, 1972; D. Dagget, oral commun., 1983; this study). Numerous prospects, anomalous in Au-Ag-Cu-Pb-Zn-Mo, occur along moderately to steeply north-dipping, east-west-trending faults along the high ridge south of the Taos Ski Area (Fig. 5; Jones, unpubl., 1982–83).

From South Fork west to Gallina Creek the style of mineralization changes. Aside from minor base and precious metal occurrences near the mouth of South Fork and Gavilan Canyon, molybdenum mineralization associated with felsic intrusive rocks is the dominant form of metallization. At South Fork quartz-molybdenite veining is exposed over an area of 4 km^2 (Fig. 5; Jones and Norris, 1984). The most widespread and intense alteration at South Fork occurs along an east-west-trending, steeply north-dipping fault zone along the north face of South Fork Peak (Jones and Norris, unpubl., 1982). Similarly, the north contact of the larger granite stock at South Fork trends nearly east-west and dips steeply to the north, apparently a fault contact (Jones and Norris, unpubl., 1982). Scattered east-west-trending quartz-molybdenite veins are found between South Fork and Gallina Creek, localized along faults associated with the east-west-trending rhyolite dike swarm (Lindgren et al., 1910; Jones, unpubl., 1983). A detailed hydrogeochemical survey conducted along the Rio Hondo drainage (Jones and Norris, 1984, fig. 9) indicates highly anomalous molybdenum concentrations along a continuous trend from South Fork towards Gallina Creek. Recent drilling at the La Virgen prospect at the mouth of Gallina Creek has intercepted significant molybdenum mineralization (approx. 400 ft of >200 ppm Mo; J. Loghry, oral commun., 1990). Although the structural controls at La Virgen are unclear due to poor exposure, the prospect area lies at the west edge of the rhyolite dike swarm (Fig. 5).

The change in style of mineralization along the Rio Hondo from molybdenum dominant in the west to base and precious metals dominant in the east is similar to that observed along the lower Red River (Clark and Read, 1972). Deeper levels of erosion along the western front of the mountains have more deeply exposed potential molybdenum source intrusions. To the east, where Tertiary sediments are preserved, precious metals mineralization may reflect distal zoning with respect to deeper molybdenum-bearing hydrothermal systems.

DISCUSSION

The prior sections briefly outline the lithologic, structural and metallization features which define a continuous ring-fracture zone from the town of Red River to Gallina Creek. Although faulting locally has followed lithologic contacts and foliations in Precambrian rocks, the offset of Oligocene volcanic rocks and the Rio Hondo pluton (26–25

Ma) indicates that faulting was a mid-Tertiary event. The age of faulting is further bracketed by the Relica Peak rhyolite and the granite stock along South Fork (Lucero Peak granite equivalent?—21 Ma) which have intruded these faults with little apparent subsequent fault movement. The age of major faulting thus lies between 26 and 21 Ma.

Where documented, displacement across the fault zone is down to the north or west. The magnitude of displacement is uncertain. At Frazer Mountain it is known to be at least 160 m and may be much greater as faulting has brought rocks of amphibolite and greenschist facies into contact (Restrepo, 1972). Along the Red River, displacement may be greater than 1000 m (Lipman and Reed, 1989). These structural data indicate that the ring-fracture zone marks the southern boundary of an east-west elongate collapse feature.

The age of faulting and the nature of displacement indicate a possible association with the development of the Questa caldera. Earlier workers (Clark, 1966; Carpenter, 1968) speculated that the Red River ring structure, a portion of the feature identified in this paper, was possibly caldera-related. However, the lack of thick accumulations of welded tuff within this collapse feature precludes it from representing a classic San Juan or Valles-type caldera. Furthermore, intrusive rocks of intracaldera tuff affinity have not yet been identified in the areas discussed. Such rocks would be present along the ring-fracture zone if it served as an ash-flow vent. The argument presented here is that the ring-fracture zone is a collapse feature related to the venting of the source magma chamber of the tuff. However, little to no tuff vented along this southern fracture zone and the degree of collapse was not sufficient to pond great thicknesses of tuff. Instead, the Questa caldera was hinged along this southern break and vented further to the north in a more central portion of the collapse block. In this model the northern margin of the Questa caldera remains as currently defined, the southern boundary is the ring-fracture zone described in this paper, and the southern caldera boundary of Figure 2 is an intracaldera nested collapse feature.

ACKNOWLEDGMENTS

Field support during the summer of 1983 was, in part, provided by Noranda Exploration, Inc. Valuable discussions and information were provided by Jack Reed and Peter Lipman.

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