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Low-Sulfidation Volcanic-hosted Epithermal Gold-Silver Deposits of West-Central Nevada

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8.6 Recent Progress in Understanding Caldera Development and Mineralization in the southern Toquima Range near Round Mountain, Nevada

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The southern Toquima Range near Round Mountain has numerous mineral deposits and areas of alteration associated with igneous activity, most notably the large precious metal deposit at Round Mountain (fig. 1). Major episodes of alteration and ore formation occurred in (1) the Cretaceous, associated with granitic intrusions; (2) in the mid-Tertiary around 26 Ma, associated with major calderas; and (3) as young as 16 Ma, spatially but not temporally or genetically associated with calderas (Tingley and Berger, 1985; Shawe et al., 1986; Mills et al., 1988; Shawe, 1988; Sander and Einaudi, 1990; Boden, 1992; Henry et al., 1996). This brief report focuses on the Tertiary episodes and their relation to caldera structure and timing.

The geology and development of calderas in the region have been intensely studied by Boden (1986, 1992) and Shawe and coworkers (Shawe, 1981, 1995; Shawe et al., 1986). New examination of key stratigraphic and structural relations, petrographic-geochemical studies, and geochronology (fig. 2) allow further refinement of the exceptional geologic framework they provided.

The Dry Canyon caldera, which erupted the tuff of Dry Canyon at about 32.2 Ma, is the oldest caldera in the Round Mountain area (figs. 1 and 2). The caldera lies just north of Round Mountain and, like the Round Mountain caldera, is largely buried beneath basin fill in Big Smoky Valley. The caldera's existence is demonstrated by the presence of thick, densely welded tuff that pinches out abruptly eastward against its caldera wall and that contains large blocks (megabreccia) of Paleozoic rocks up to 300 m in diameter. No mineral deposits are known to be associated with the Dry Canyon caldera.

The earliest magmatism within what is known as the Toquima caldera complex (Boden, 1986, 1992; Mills et al., 1988) was eruption of the tuff of Corcoran Canyon at ~29.6 Ma. The tuff may be as much as 2000 m thick, although repetition by faulting is uncertain, and it contains megabreccia (Boden, 1992). Tuff with these characteristics almost certainly accumulated within its own caldera, so I interpret a Corcoran Canyon caldera to have formed in the southeastern part of the Toquima caldera complex. This caldera is now largely obscured by younger calderas and by Basin and Range faulting. The tuff of Corcoran Canyon hosts the Corcoran Canyon deposit (Mills et al., 1988; Boden, 1992). However, alteration associated with the deposit affects a rhyolite dome that is ~26.9 Ma (fig. 1), so the deposit is more than 2.5 Ma younger than formation of the Corcoran Canyon caldera.

At least two other ash-flow tuffs accumulated in the Toquima area before about 27 Ma (figs. 1 and 2). The tuff of Ryecroft Canyon (27.08±0.09 Ma) is up to 1000 m thick in the southeastern part of the Toquima caldera complex and also contains breccia (Boden, 1992). These characteristics suggest it also accumulated within an older and now largely obscured caldera. The presence of early rhyolite domes along the southern edge of the Toquima caldera complex is further support for early calderas. One body lies in the wall of the Moores Creek-lower Mount Jefferson caldera and is 27.14±0.06 Ma. Another rhyolite, aphyric and therefore undated, is overlain by the tuff of Mount Jefferson at the Jefferson deposit and must be older than formation of the Mount Jefferson caldera at about 26.7 Ma (fig. 1). Similar "ring-fracture" rhyolites formed along the margins of the Moores Creek-lower Mount Jefferson and Mount Jefferson calderas shortly after collapse of those calderas (figs. 1 and 2). The tuff of Logan Spring (27.03±0.08 Ma) is a volumetrically minor tuff with no known source in the northeastern part of the complex. No mineralization is known to be associated with either tuff.

The Moores Creek-lower Mount Jefferson caldera is the largest of the area, being at least 30 km north to south (fig. 1). The cumbersome name comes from the fact that I have combined two calderas (Moores Creek and Trail Canyon) and three tuffs (Moores Creek, lower tuff of Mount Jefferson, and lower tuff of Trail Canyon) mapped by Dave Boden (Boden, 1992). This new correlation is based on distribution of thick (up to 1300 m), breccia-rich, intracaldera tuff with indistinguishable ages and association with rhyolite domes, also with indistinguishable ages (figs. 1 and 2). Age determinations on four of five samples of the combined tuff range from 26.90 to 26.95 Ma, and one is 26.83 Ma. Ages of rhyolite domes along the margin of the combined caldera cluster even more tightly between 26.93 and 26.96 Ma. The domes were emplaced almost immediately after ash-flow eruption and caldera collapse and presumably tapped the same magma chamber that erupted tuff. Mineralization in Corcoran Canyon lies near the margin of the Moores Creek-lower Mount Jefferson caldera, involves one of the rhyolite domes, and could be genetically related to the caldera.

The next major caldera was the Mount Jefferson caldera, which is about 20 km in diameter. It is nested within the Moores Creek-lower Mount Jefferson caldera (fig. 1) and shows a similar evolution. The tuff of Mount Jefferson (Boden's upper tuff of Mount Jefferson) erupted about 26.7 Ma (three ages are 26.68±0.12, 26.64±0.09, and 26.66±0.05 Ma) and ponded within the caldera to as much as 1200 m thick (Boden, 1992). Numerous rhyolites intruded along the ring fracture shortly afterward; ages of five rhyolites range from 26.54 to 26.65 Ma. Three areas of alteration-mineralization are spatially associated with the Mount Jefferson caldera (fig. 1). These are Gold Hill and Jefferson, both of which produced gold and silver from the tuff of Mount Jefferson, and Moores Creek, an area of modest alteration in the lower tuff of Mount Jefferson in the northwestern part of the caldera. The timing of mineralization is known only for Gold Hill, where adularia gives an age of 25.97±0.05 Ma. Interestingly, this is indistinguishable from ages of mineralization at Round Mountain, which lies just 8 km to the south.

The 26.5-Ma tuff of Round Mountain, its caldera, and the 26.0-Ma Round Mountain deposit are thoroughly described elsewhere (Tingley and Berger, 1985; Sander and Einaudi, 1990; Boden,

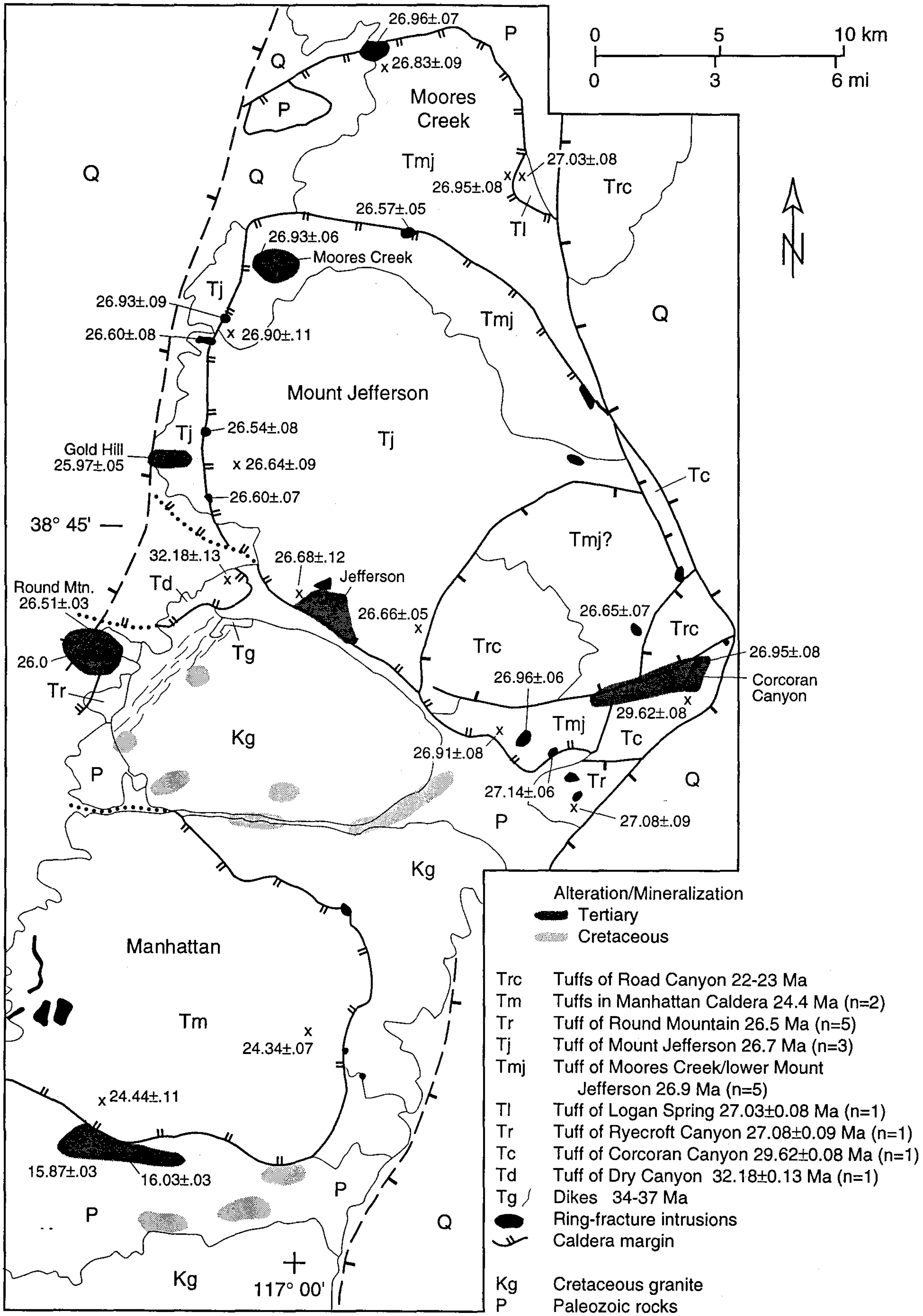

FIGURE 1. Simplified geologic map showing calderas, ash-flow tuffs, ring-fracture rhyolites, and mineralized areas of the Toquima Range near Round Mountain (modified from Boden, 1986, 1992, and Shawe, 1988).

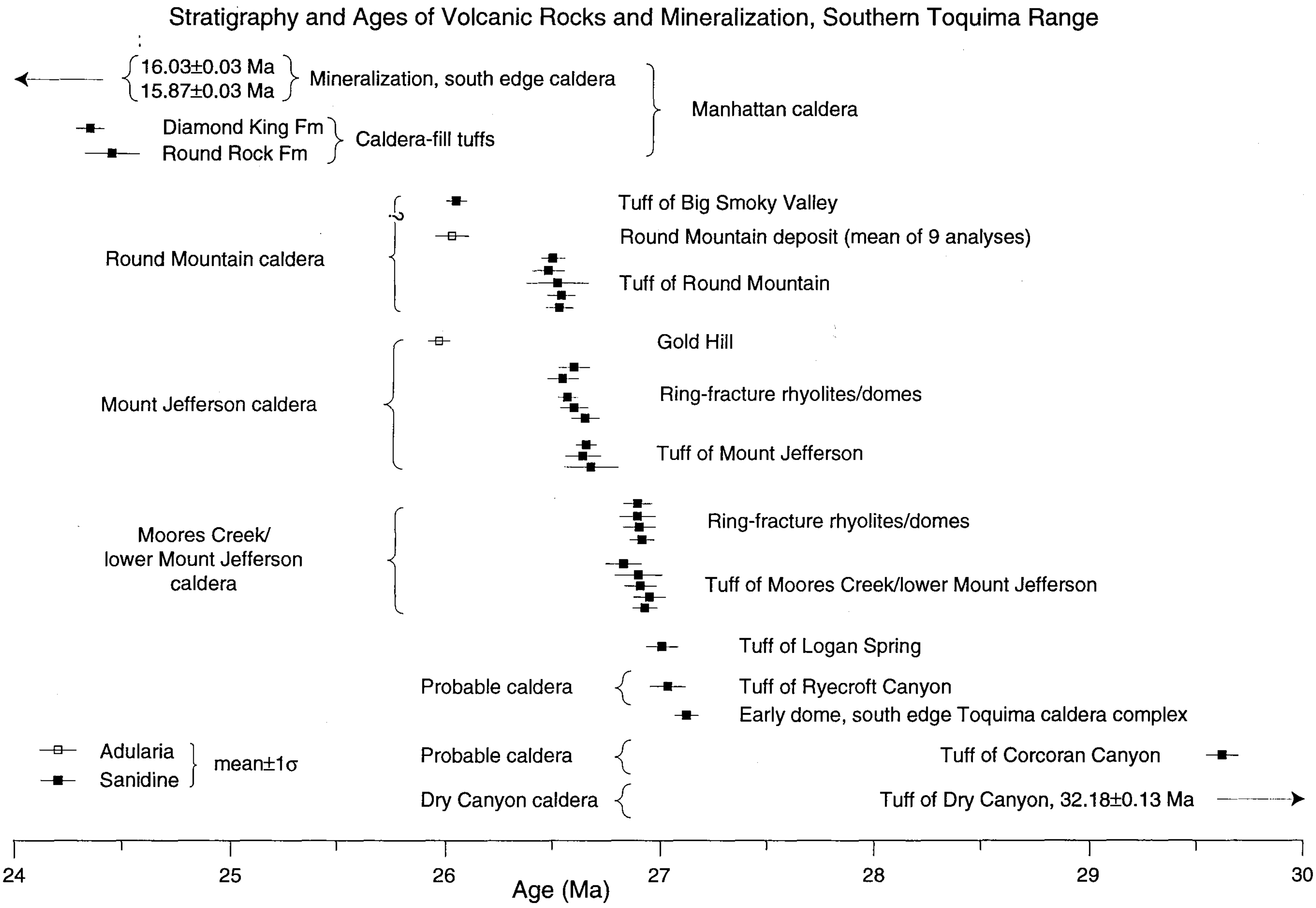

FIGURE 2. Stratigraphy and $^{40}Ar/^{39}Ar$ ages (with 1s error bars) of volcanic rocks and mineralization in the calderas of the southern Toquima Range. Ages of volcanic rocks are from single crystal analyses of sanidine; ages of mineralization are from step heating of adularia. Volcanic rocks are plotted in ascending stratigraphic order determined from field relations and/or ages.

1992; Henry et al., 1996). A significant point is that three major calderas formed in the Mount Jefferson-Round Mountain area in a time span of no more than 0.5 Ma, a remarkably intense period of volcanism. Another important point to consider is that, other than the presence of the Round Mountain deposit, the Round Mountain caldera is much like all the other calderas in the area.

The Manhattan caldera is also similar to other calderas in the area, but its mineralization is distinctive in being much younger than caldera magmatism. Shawe (1981) and Shawe and Snyder (1988) mapped two intracaldera tuffs, the lower Round Rock Formation and an upper Diamond King Formation. They give indistinguishable ages of 24.44±0.11 and 24.34±0.07 Ma, respectively. Ring-fracture rhyolites and latites are common near the western and along the eastern margin of the caldera. K-Ar ages of these are around 24 Ma (Shawe et al., 1986) but not sufficiently precise to determine their timing other than post-ash-flow tuff. Mineralization of the Manhattan district lies along the southern margin of the caldera, mostly in Paleozoic rocks that make up the caldera wall. However, adularia from April Fool Hill and the white ore vein give ages of 16.03±0.03 and 15.87±0.03 Ma, respectively. These ages are 8 Ma younger than ash-flow eruption and caldera collapse, and the domes are unlikely to be significantly younger than the tuffs. Therefore, mineralization at Manhattan is not temporally or genetically related to caldera magmatism. Similar situations, i.e., of mineralization that is structurally related to a caldera but much younger than caldera magmatism, are common in the San Juan volcanic field in Colorado (Lipman et al., 1976). However, in the San Juan Mountains, mineralization hosted by older rocks is commonly contemporaneous with igneous activity in an adjacent, younger caldera. Igneous activity at 16 Ma is not known at Manhattan but was common near Tonopah to the south (Bonham and Garside, 1979). Mafic-intermediate rocks occur as close as about 15 km to the south, and rhyolitic domes are within 35 km. It is possible that similar rocks occur closer to Manhattan and drove hydrothermal circulation there but do not crop out or have not been distinguished from mid-Tertiary igneous rocks.

Mineral deposits and areas of alteration in the Round Mountain area show a range of settings and timing related to calderas. All appear to lie along or close to caldera ring fractures; no significant deposits or altered areas have been found within the middle of calderas. Certainly, the ring fracture zone should provide exceptional conduits for circulation of hydrothermal fluids. However, faults within calderas, which are abundant in the Mount Jefferson caldera (Boden, 1992), could also be good conduits. The Round Mountain deposit formed approximately 0.5 Ma after ash-flow eruption and caldera collapse and is reasonably interpreted to have been driven by ring-fracture intrusion (Henry et al., 1996), which is obviously common around the Toquima area calderas. Within the Toquima caldera complex, precise timing is known only for the Gold Hill deposit, which is the same as at Round Mountain. Other deposits probably formed close in time to igneous activity, but this needs to be tested. Because ring-fracture rhyolites are widespread, all areas of alteration in the Toquima calderas lie within a few kilometers of such rhyolites. However, mineralization at Gold Hill is distinctly younger than the two nearby rhyolites, and mineralization at Jefferson is younger than the rhyolite there, which is older than the tuff of Mount Jefferson. Most of the ring-fracture rhyolites do not have associated alteration, and none of them can be specifically related to any deposit. Ore deposits at Manhattan formed ~8 Ma after caldera activity; the caldera ring fracture may have provided plumbing for hydrothermal circulation, but heat and metals could not have come from caldera-related magmas. Calderas should be ideal locations to develop major ore deposits because they combine sources of heat, metals, and fluids with great plumbing, yet several calderas in the southern Toquima Range have no known associated deposits or areas of alteration. I wish I could tell you why some worked and some didn't, but I can't.

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