Oligocene calderas, mafic lavas and radiating mafic dikes of the Socorro-Magdalena magmatic system, Rio Grande rift, New Mexico: surface expression of a miniplume?

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Common traits of mantle plumes are:1) domal uplift prior to volcanism, 2) a definite age progression along a volcanic chain, 3) long mafic dikes that radiate from the volcanic core, 4) large basaltic plateaus or shield volcanoes, and 5) petrochemical indicators of anomalously high temperature melt zones in the upper mantle, such as high Ni/MgO ratios in picritic basalts (Campbell, 2001). We suggest the Socorro-Magdalena magmatic system of Oligocene age (Fig.1, eruptive volume 7100 km^3) exhibits characteristics similar to a mantle plume, but at 1/10-1/100th the scale of a deep mantle plume, which may qualify it as a miniplume?

A cluster of five overlapping ignimbrite calderas is moderately well exposed in strongly extended, tilted fault-block mountain ranges of the central Rio Grande rift southwest of Socorro NM (Fig.1). The westward younging Socorro-Magdalena caldera cluster (SMCC) is 85 km long and 20-25 km wide. It parallels the southeastern margin of the Colorado Plateau and the WSW-trending San Agustin arm of the rift. The latter produces the appearance of an incipient triple junction within the dominantly north-trending rift system. Precise $^{40}Ar/^{39}Ar$ ages of sanidines from the rhyolite ignimbrites and detailed geologic mapping demonstrate that the distended calderas become progressively younger to the west-southwest (McIntosh et al., 1991: Chamberlin et al., in press). Large volume ignimbrite eruptions occurred at 31.9, 28.7, 27.9, 27.4 and 24.3 Ma. A large satellitic caldera, which formed at 28.4 Ma, is located 20 km southwest of the main overlapping trend. A small collapse structure, which is nested in the Socorro caldera, erupted at 30.0 Ma. The total volume of densely welded ignimbrite and moat-fill lavas erupted from the SMCC is 5500 km^3.

Within 40 km of the northeastern margin of the caldera cluster, the rhyolite ignimbrites are interleaved with a 400-700 m thick plateau-like belt of basaltic andesite lavas (Fig.1). These mafic lavas are assigned to the La Jara Peak Basaltic Andesite (Osburn and Chapin, 1983a). They range from slightly alkaline trachybasalt to moderately alkaline basaltic trachyandesite and sub-alkaline basaltic andesite. Sparse small phenocrysts of olivine, commonly altered to reddish brown iddingsite, are characteristic. Phenocrystic plagioclase, indicative of differentiation at depths less than 30 km (Wilson, 1989), is typically absent. Individual basaltic andesite flows are commonly 7-10 m thick. Stacked flows between ignimbrites have an aggregate thickness of as much as 330m and locally define wedge-shaped prisms formed by domino-style extension in the early Rio Grande rift (Chamberlin, 1983; Ferguson, 1991). A 32-33 Ma flow and tephra unit near La Joya was locally fed by a short NE striking basaltic-andesite dike that appears to radiate from the 31.9-Ma Socorro caldera (Fig1). A primitive trachybasalt in the SE moat of the Socorro caldera (~31 Ma; Chamberlin et al., in press) contains 9.3 % MgO and 170 ppm Ni; this suggests a relatively hot source zone in the mantle, compared to most subduction related basalts (Campbell, 2001). The total volume of Oligocene basaltic andesite lavas peripheral to the SMCC is 1600 km^3. The maximum rate of basaltic andesite eruption, ~1800 km^3/Ma, was coeval with the zenith of domino-style extension and apparent caldera migration at 27.9-27.4 Ma.

Moderately alkaline to sub-alkaline basaltic andesite and trachybasalt dikes of Oligocene age (31-24 Ma, K/Ar, Aldrich et al., 1986; Laughlin et al., 1983) form a large semi-continuous radial array that is broadly focused on the SMCC (Fig.1). The Magdalena radial dike swarm (MRDS) fans through

220° of arc from Pie Town clockwise to Acoma, Chupadera, Bingham and Elephant Butte. The maximum radius of the MRDS is 125 km; subswarms of near parallel dikes are commonly 20-75 km long. The mafic dikes are commonly fine grained or diabasic, medium to dark gray, and often contain microphenocrysts of olivine, which may be altered to iddingsite. Phenocrystic plagioclase is usually absent. Longer dikes are typically basaltic andesites (53 -56 wt. % SiO_2). Within the NW-striking Pie Town subswarm, exposed dike length (75, 24 and 2 km) decreases with increasing MgO content (3.1, 5.9 and 8.0 wt. %, respectively; Baldridge et al., 1989). This is consistent with dominantly horizontal flow and lateral intrusion of magma at different levels of neutral buoyancy (Fig.2). Shorter NNE- and NNW-striking dikes near Riley are more numerous and closely spaced than in other sectors of the MRDS. Some of the shorter dikes were probably coin-shaped feeder dikes similar to the 32-Ma dike at La Joya. Cross cutting relationships of intersecting dikes near Riley and La Joya are generally consistent a westerly migrating focus of mafic magmatism. However, one NNW striking dike south of Riley exhibits bifurcations to the NNE, is cut by a NNE striking dike and terminates in a NNE bend. These dike patterns and similar orientations of early rift faults suggest a complex interplay of short-term magmatic stresses and longer-term plate stresses. New $^{40}Ar/^{39}Ar$ data for dikes near Riley (Fig.1) demonstrate that they were emplaced during the peak of regional extension, caldera migration, and mafic volcanism. Several NNE-striking dikes near Riley also contain granitic xenoliths that exhibit magmatic reaction rims. Collectively, the above observations imply that radial dikes of the Magdalena swarm are most likely linked at depth with a westerly migrating mafic sill complex in the lower crust under the caldera cluster (Fig.2). Presumably the inferred mafic sill complex also fueled rhyolite generation in the caldera cluster. Projections of mafic dikes shown on Figure 1 commonly intersect about 5-10 km north of the caldera cluster; this suggests that the inferred lower crustal sills are larger in diameter than the overlying calderas.

A sequentially rising diapir chain, associated with rollback of the Farallon slab through the upper mantle, is suggested as a reasonable mechanism to produce the observed westerly migrating calderas and surrounding mafic magmatism (Fig.3). Slab rollback may have created a westward migrating diapir source zone (Rayleigh-Taylor instability; Olson, 1990) that fed a sequentially rising chain of diapirs, thus producing the apparent westward migration of magmatism in the overlying crust. Alternatively, westward flow in the upper mantle wedge may have tilted a rising diapir and sheared it into multiple segments (Whitehead and Helfrich, 1990). Regional east-west extension in the early rift at this time also implies westward stretching at a rate greater than westward drift of the North American plate. Indications of regional doming prior to Oligocene mafic volcanism at Socorro are presently unclear; if present, the expression must be subtle. Cycles of pre-caldera tumesence and post-collapse resurgence are, however, locally evident within the eastern section of the caldera cluster (Chamberlin et al., in press). The SMCC is underlain by a broad Laramide uplift of early Tertiary age, which is generally attributed to regional crustal shortening.

The tectonic setting of the Socorro-Magdalena magmatic system is somewhat unique. The Socorro system lies at the north end of a 1500-km long magmatic arc of Eocene to Oligocene age. The arc locally terminates against relatively rigid microplates of the Colorado Plateau and the Great Plains near Socorro. The Socorro region also appears to occupy an incipient triple junction (now abandoned?) within the Rio Grande rift system. If our model is correct, then the contrast between basaltic plateau volcanism to the north, small shield volcanism to the west (Fig.1), and satellitic rhyolite volcanism to the south can be largely attributed to lateral variations in the thermal regime of the crust at that time. Regional map relationships also suggest that mafic dikes propagating through the lower crust may interconnect with deep plumbing systems of separate magmatic centers as much as 100 km distant.

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OLIGOCENE CALDERAS, MAFIC LAVAS AND RADIATING MAFIC DIKES OF THE SOCORRO-MAGDALENA MAGMATIC SYSTEM

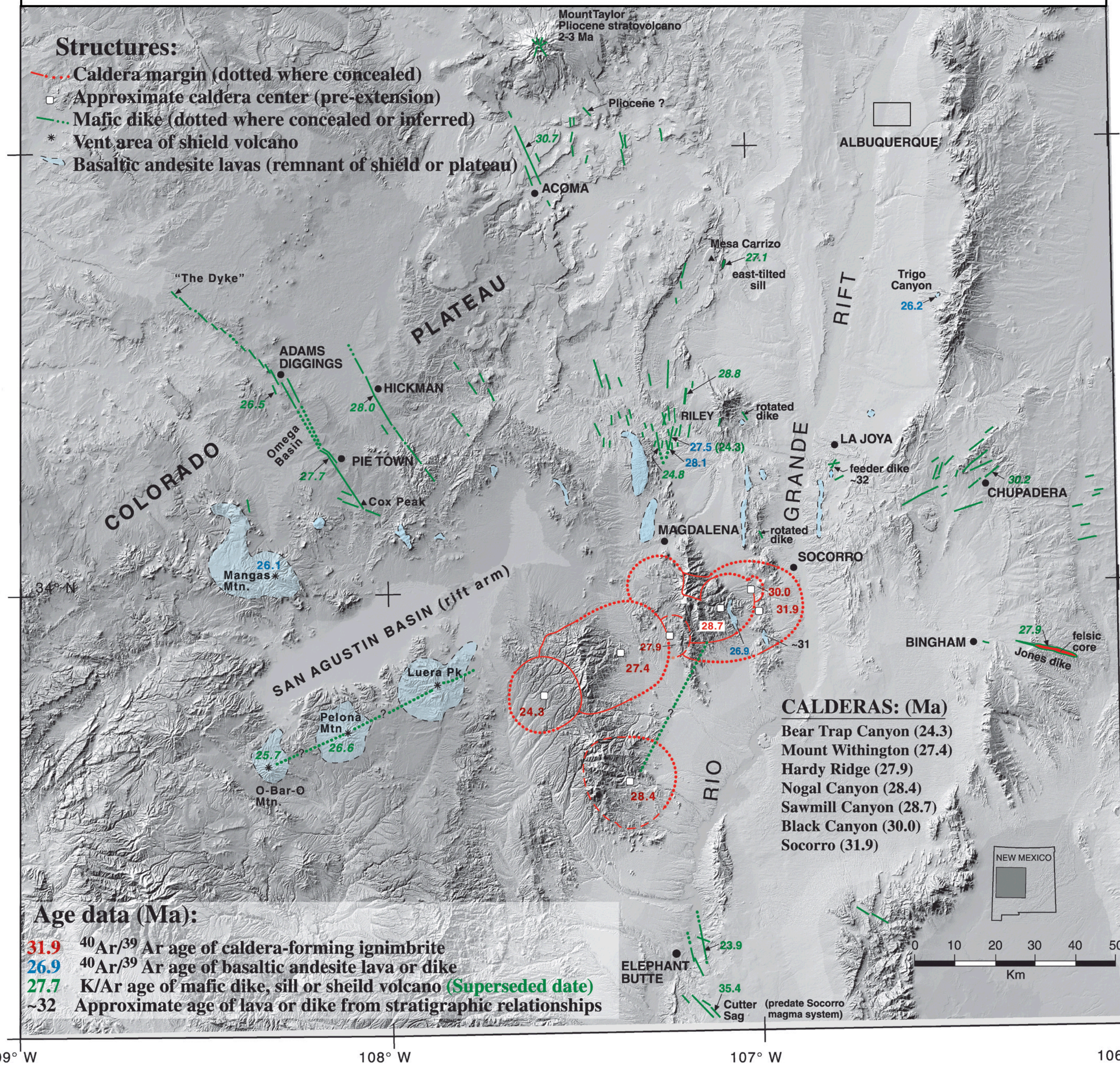

Figure 1. Oligocene calderas, mafic lavas and radiating mafic dikes of the Socorro-Magdalena magmatic system (after Chamberlin et.al., 2002). Data sources are listed at http://geoinfo.nmt.edu/staff/chamberlin/mrds/Chamberlin_2002_GSA_poster.pdf

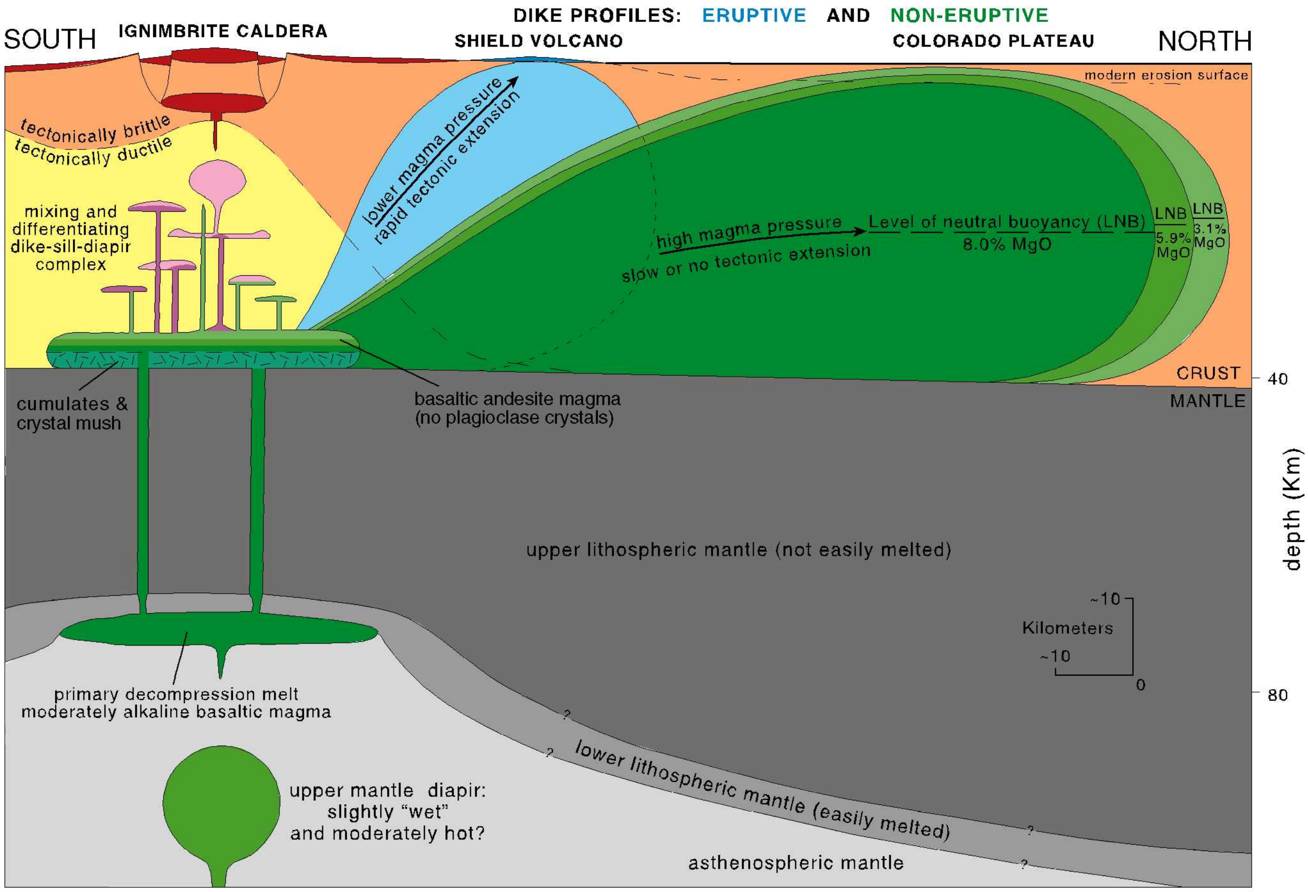

Figure 2. North-south cross-sectional model of the Socorro-Magdalena magmatic system at ~ 28 Ma (after Chamberlin et.al., 2002).

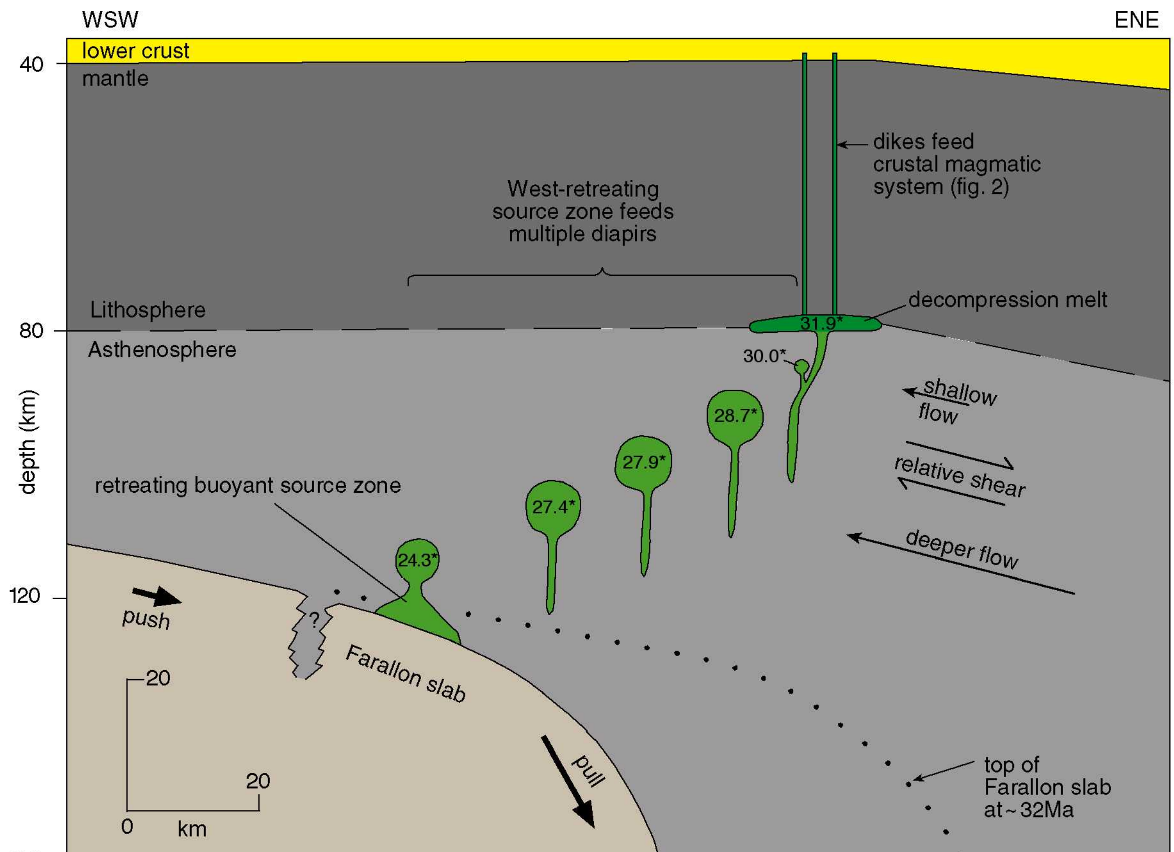

Figure 3. East-west cross sectional model of an upper mantle diapir chain associated with rollback of the farallon slab in Oligocene time (after Chamberlin et.al., 2002).