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GEOLOGY OF MID-TERTIARY VOLCANIC ROCKS OF THE EAST-CENTRAL BLACK RANGE, SIERRA COUNTY, NEW MEXICO: IMPLICATIONS FOR A DOUBLE-CAULDRON COMPLEX IN THE EMORY CAULDRON

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Abstract—The Emory cauldron is a north–south elongated, complex eruptive center that may consist of two distinct cauldrons. Despite petrographic similarity and continuous nature of the Kneeling Nun Tuff throughout the complex, associated moat sequences contain andesitic intrusives in the north and rhyolitic intrusives in the south. An arcuate intrusion, associated with the moat deposits in the northern ring-fracture zone, is hypothesized to be the septum region between the two cauldrons.

A megabreccia zone parallels the eastern section of a 180° sinuous fault trace that is interpreted as the structural cauldron margin. Resurgence produced a north-trending apical horst block that is west-stepped in relation to the southern resurgent block of the Emory cauldron. Basin and Range faulting also trends north, implying fundamental control of the regional fabric by basement structures. The reverse motion along structural-cauldron-margin faults is thought to have developed during resurgence and continued to the present.

INTRODUCTION

The southern Black Range is the resurgent horst block of one of the largest mid-Tertiary ignimbrite calderas in New Mexico (Elston 1984), the Emory cauldron (Fig. 1). Initial studies of the cauldron were confined to accessible southern parts of the Black Range (Elston et al. 1975, Seager et al. 1978, O'Brien 1979, Farris 1981, Maggiore 1981) and, from the earliest two studies, the cauldron margin was inferred to be elliptical, elongated north–south. However, an early reconnaissance and aerial-magnetic survey by Ericksen et al. (1970), of the entire Black Range Primitive Area, produced an aerial-magnetic map that suggested the existence of a nested complex. Recently, detailed mapping (1:24,000) in the central Black Range (Fig. 2; Abitz 1984, 1985) elucidated stratigraphic and structural relationships that now seem to suggest the Emory cauldron may be a double-cauldron complex. Documentation of the northern eruptive center is still in progress and results reported herein are preliminary.

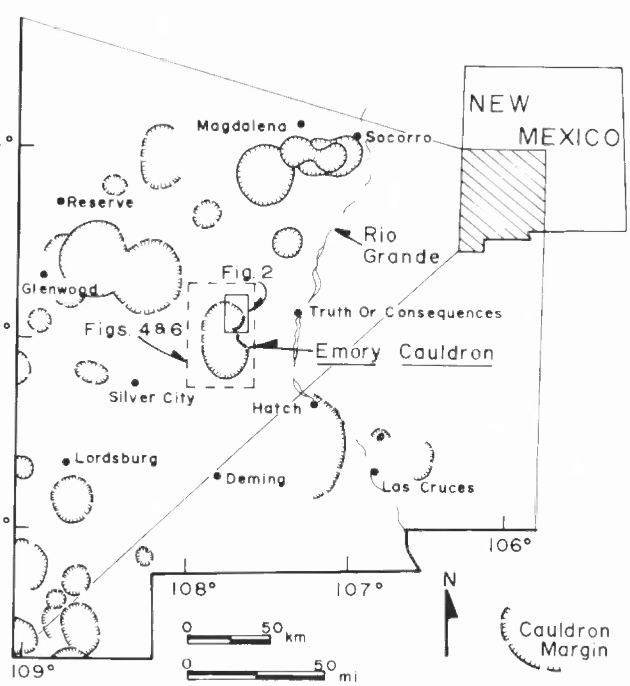

FIGURE 1—Location of Emory cauldron complex within Mogollon–Datil volcanic field.

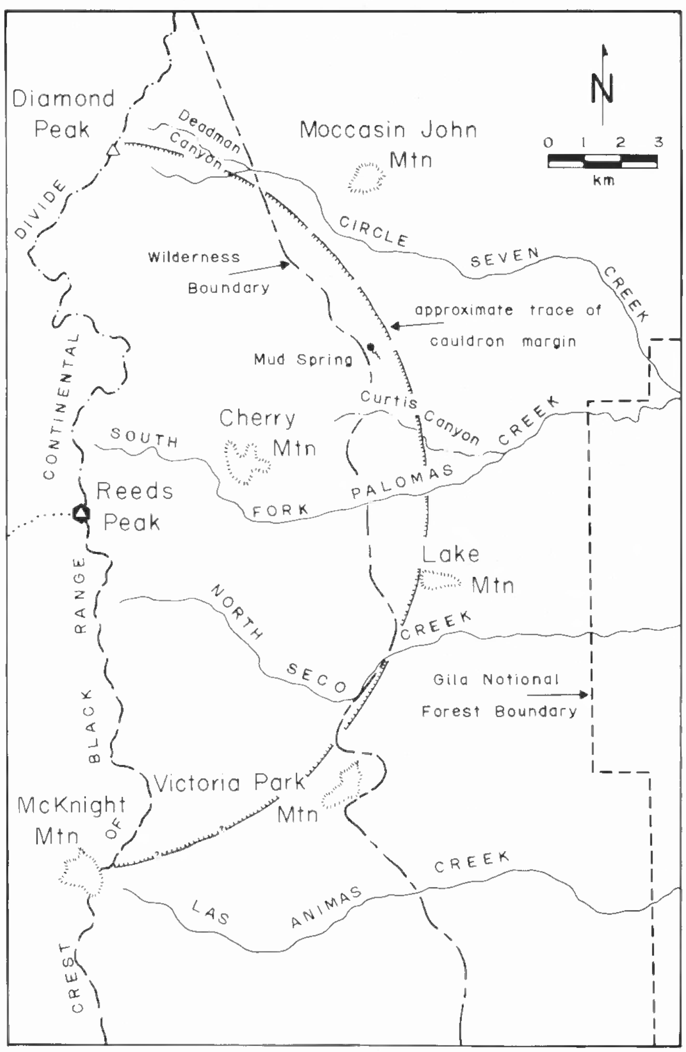

FIGURE 2—Location of principal geographic features within and adjacent to northern Emory cauldron. Hachures on cauldron-margin trace do not necessarily indicate downside.

Volcanic-rock units (Fig. 3) are conveniently discussed in three temporal settings for the stratigraphic discussion: (1) pre-cauldron, (2) syn-cauldron, and (3) post-cauldron. These three volcanic lithozones are extended over the entire cauldron complex by correlating previous and present work within and adjacent to the Emory cauldron (Fig. 4). Suggested correlations are given in Fig. 5.

STRATIGRAPHY

Pre-cauldron rocks

The Rubio Peak Formation of Jicha (1954) consists of basaltic-andesite, andesite, and agglomerate flows deposited in latest Eocene or earliest Oligocene (Loring & Loring 1980). Fractured, propylitized andesite flows occur on the east side of the ring-fracture zone, along North Seco Creek, and as megabreccia blocks within intracaldera tuff. The mineral assemblage is variable. Megabreccia blocks contain 10–15% phenocrysts of hornblende, plagioclase, augite, and traces of opaques and apatite. The propylitized flows are chiefly composed of epidote and chlorite, with rare relict cores of plagioclase and augite. The name Rubio Peak Formation was extended to the southern Black Range by Elston et al. (1975) and has been used by all subsequent workers. The early andesite of Ericksen et al. (1970) is partly correlative to the Rubio Peak Formation (Fig. 5).

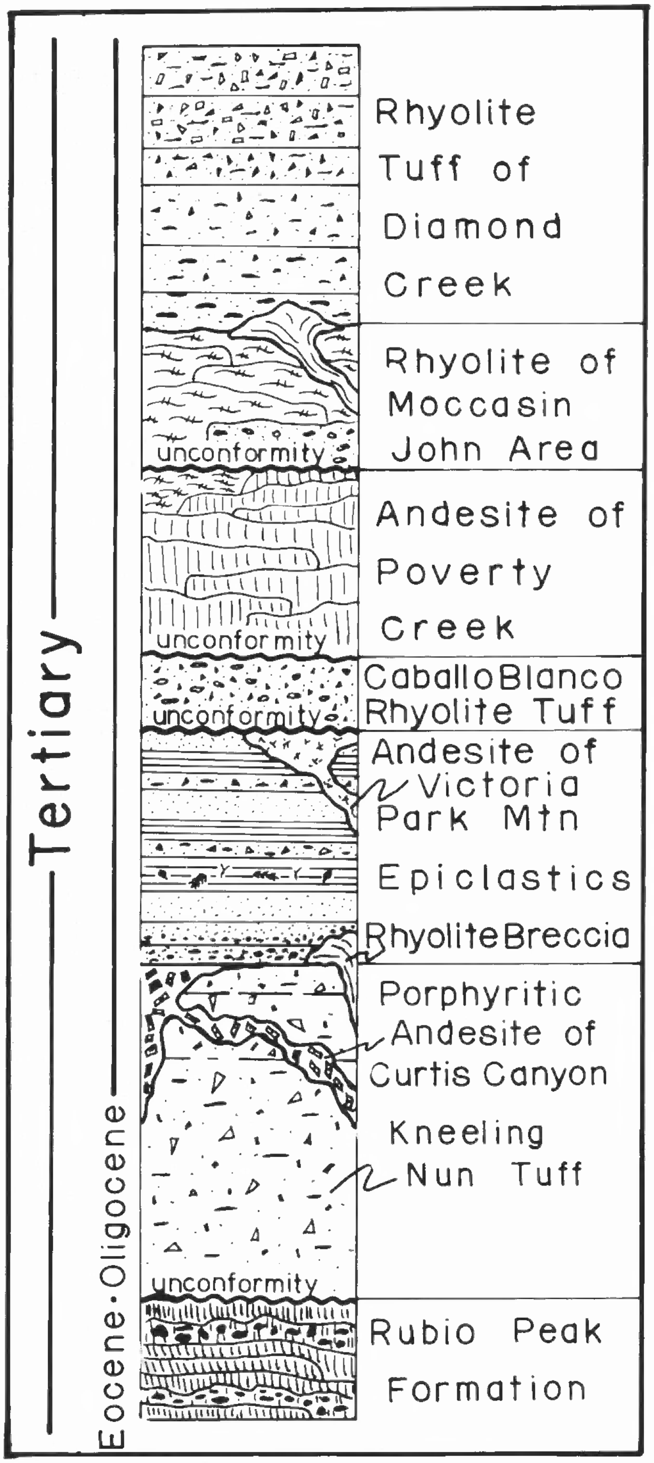

FIGURE 3—Stratigraphic column of volcanic rocks within and adjacent to northern Emory cauldron.

Syn-cauldron rocks

Four mapping units comprise the northern-cauldron rock suite: (1) Kneeling Nun Tuff, (2) porphyritic andesite of Curtis Canyon, (3) volcaniclastics of the Hermosa region, and (4) rhyolitic breccias.

The Kneeling Nun Tuff (Jicha 1954) is a quartz latite, crystal-rich ash-flow tuff containing 35–50% phenocrysts of plagioclase, sanidine, quartz, and biotite, lithic fragments, and scarce pumice. The matrix is gray to lavender and moderately to densely welded. Restricted to intracaldera facies within the study area, the tuff crops out in massive sections, greater than 300 m, south of Circle Seven Creek on the east side of the Continental Divide. A basal contact is not exposed within the study area, but to the north, east, and south outflow facies lie unconformably over the Rubio Peak Formation (Seager et al. 1982, Abitz 1984, Harrison in this guidebook). Elston et al. (1973) reported a K–Ar age of 33.4 ± 1.0 my (all K–Ar ages are corrected for new decay constant according to the method of Dalrymple 1979) for the southern Kneeling Nun Tuff. O'Brien (1979) reported K–Ar ages of 33.0 ± 1.2 my and 33.6 ± 1.3 my for coeval hypabyssal rhyolitic rocks

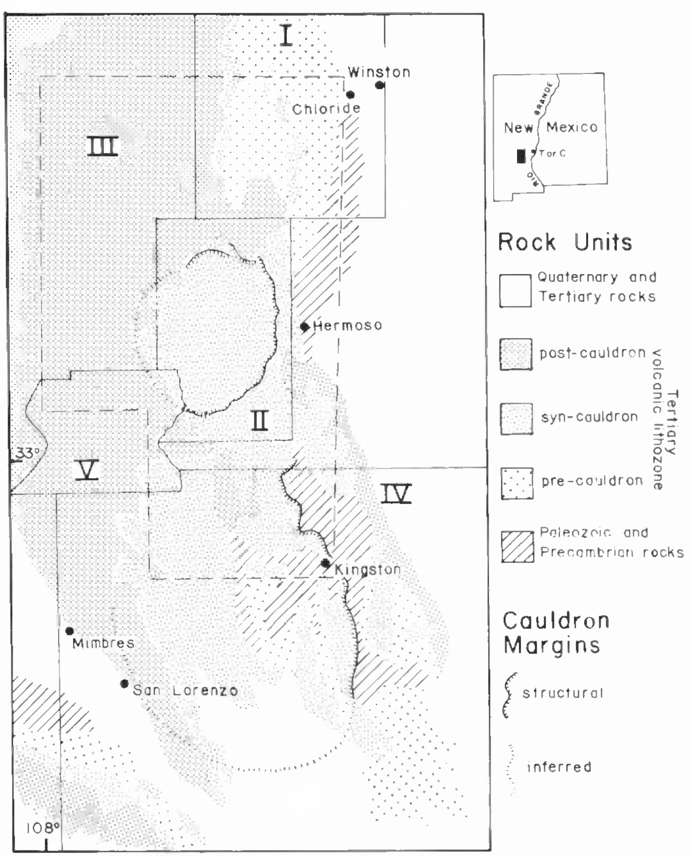

FIGURE 4—Simplified geologic map of Emory cauldron complex showing regions of previous and continuing studies: I = Harrison (this guidebook); II = Abitz (unpubl.); III = Ericksen et al. (1970); IV = Seager et al. (1982); V = Farris (1981). Hachures on northern structural-margin faults do not necessarily indicate downside.

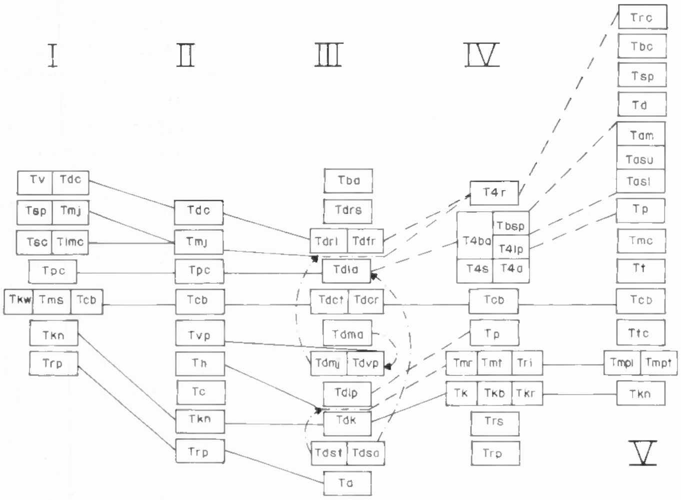

FIGURE 5—Stratigraphic-correlation diagram for volcanic rocks within and adjacent to Emory cauldron complex. I = Harrison (this guidebook); II = Abitz (unpubl.); III = Ericksen et al. (1970); IV = Seager et al. (1982); V = Farris (1981). Solid line = correlation certain; dashed line = correlation probable; dot–dash with arrow = corrected stratigraphic position. Ta = early andesite sequence; Alum Mountain Group, Tam = basaltic andesite of Middle Mountain, Tasl = lower member, Tasu = upper member; T4a = intermediate-composition lavas and breccias; Tba = basaltic andesite of Hodge Canyon; T4ba = basaltic andesite and other intermediate composition flows; Tbc = Bloodgood Canyon Rhyolite Tuff; Tbsp = Bear Springs Basalt; Tc = andesite of Curtis Canyon; Tcb = Caballo Blanco Rhyolite Tuff; Tcm = tuff of Cherry Mountain; Td = rhyolite tuff of Davis Canyon; Tdc = tuff of Diamond Creek; Tdcr & Tdct = Caballo Blanco Rhyolite Tuff; Tdfr = flow-banded rhyolite of Rocky Canyon; Tdk = Kneeling Nun Tuff; Tdla = andesite of Aspen Canyon; Tdlp = latite porphyry of Holden Prong; Tdma = andesite of Mimbres River–McKnight Mountain area; Tdmj = rhyolite of Moccasin John area; Tdrl = rhyolite of Diamond Creek; Tdrs = tin-bearing rhyolite of Taylor Creek; Tdsa & Tdst = rhyolite and andesite of the Hermosa area; Tdvp = andesite flows and rhyolite tuffs of Victoria Park Mountain; Th = volcaniclastics of the Hermosa region and rhyolite breccia; Tii = intermediate-composition intrusives; Tk &Tkn = Kneeling Nun Tuff; Tkb = cauldron-breccia facies of Kneeling Nun Tuff; Tkrp = rhyolite-porphyry intrusives associated with Kneeling Nun Tuff; Tkw = tuff of Koko Well; Tlmc = tuff of Little Mineral Creek; T4lp = latite-porphyry flows and breccia; Tmc = rhyolite tuff of Monument Canyon; Tmj = rhyolite of Moccasin John area; Tmpl, Tmpt, Tmr & Tmt = Mimbres Peak Formation; Tms = Monument Park Sandstone; Tp = Pollack Quartz Latite; Tpc = andesite of Poverty Creek, Trc = rhyolite of Rock Canyon; Tri = rhyolite intrusives; Trp = Rubio Peak Formation; Trs = Sugarlump Formation; T4r = younger rhyolite; Ts = quartz-latite tuff of Shelley Peak; Tsc = tuff of Stiver Canyon; Tsp = Sawmill Peak Rhyolite; T4s = conglomerate, sandstone, and shale; Tt = quartz-latite tuff of Terry Canyon; Ttc = andesite of Turkey Cienega Canyon; Tv = tuff of Vicks Peak; Tvp = andesite of Victoria Park Mountain.

of the Raab Park complex, which he interpreted as a possible choked vent for the Kneeling Nun Tuff. McIntosh (this guidebook) obtained a slightly older age for the Kneeling Nun Tuff using the argon–argon dating method. If the Emory cauldron complex is shown to consist of two separate cauldrons, the respective ash-flow tuffs must have been very nearly coeval to occupy the same stratigraphic position. Ericksen et al. (1970) extended the name Kneeling Nun Tuff to the central Black Range, and Harrison (this guidebook) extends it to the northern Black Range.

The *porphyritic andesite of Curtis Canyon* (new name) supercedes the porphyritic andesite of North Fork Palomas Creek of Abitz (1984). The andesite is a massive lavender to purple porphyry containing 40–60% phenocrysts of plagioclase, augite, hornblende, and traces of opaques, apatite, and xenocrystic orthoclase. Restricted to narrow, irregular zones outside of the megabreccia zones, it has been interpreted as a ring-fracture extrusion, possibly coeval with the ash-flow tuff. Uncommon flows lie conformably on intracaldera Kneeling Nun Tuff. The rock is readily distinguishable in the field by its resorbed plagioclase centers. This disequilibrium texture suggests that the porphyritic andesite of Curtis Canyon may be a defluidized residue of the evolved parent magma of the Kneeling Nun Tuff. Strontium-isotope data support this contention (Abitz 1985). Ericksen et al. (1970) included the porphyritic andesite of Curtis Canyon in their early andesite sequence, below Kneeling Nun Tuff. The porphyritic andesite of Curtis Canyon can be separated from their early andesite sequence (Rubio Peak Formation) because flows have been found overlying the intracaldera Kneeling Nun Tuff. The porphyritic andesite of Curtis Canyon cannot be correlated to the southern ring-fracture zone of the Emory cauldron. Similar porphyritic andesites to the south do not display disequilibrium microtextures and lie stratigraphically higher, above the Caballo Blanco Tuff (Fig. 5).

The name *volcaniclastics of the Hermosa region* is suggested here for epiclastics interbedded with lakebeds and tuffs (moat deposits). They crop out in a concentric pattern surrounding the intracaldera Kneeling Nun Tuff and show distinct facies changes, from conglomerates to sandstones to lakebeds, as one moves radially away from the intracaldera tuff. Interbedded tuffs provide excellent markers to verify the facies changes. Monolithic conglomerates contain clasts of Kneeling Nun Tuff. The lack of heterogeneous lithics within the conglomerates is also evidence for classifying these clastics as moat deposits. The fossiliferous lakebeds contain subalpine conifer flora (Axelrod 1975). By stratigraphically bracketing the flora-bearing strata between dated volcanic units in the Hillsboro area, Axelrod (1975) suggested an age of about 32 my for the lakebeds. He extended this age to similar flora-bearing strata in the Hermosa area.

Interbedded andesite becomes volumetrically significant in the southern moat deposits. These andesite flows are equivalent to the andesite of Victoria Park Mountain of Ericksen et al. (1970) and their name is retained here. The flows originated from fissure sources on Lake Mountain and Victoria Park Mountain. Victoria Park Mountain is a massive andesite extrusive center with several hematite-stained, brecciated fissure vents. The predominant rock type has a gray and red mottled matrix with 5–10% phenocrysts of glomeroporphyritic lime-green aegerine–augite, making it very distinct from the porphyritic andesite of Curtis Canyon. The composite moat sequence ranges in thickness from about 100 to 200 m and lies nonconformably over porphyritic andesite of Curtis Canyon.

The correlation between southern and northern moat deposits is not well understood at this time. The volcaniclastics of the Hermosa region can be tentatively correlated between Hillsboro and Hermosa by subalpine flora (about 32 my; Axelrod 1975), and it can be crudely correlated to epiclastics in the southern moat of the Emory cauldron because of the similar age of the Mimbres Peak Formation (32.8 my; Elston et al. 1973). Within the study area, the rhyolite and andesite of the Hermosa region of Ericksen et al. (1970) consist of volcaniclastics, tuffs, and andesite flows. Their volcaniclastics and tuffs are correlated to the volcaniclastics of the Hermosa region because they nonconformably overlie the porphyritic andesite of Curtis Canyon and not the Rubio Peak Formation. The tuff at the top of the volcaniclastic section is correlated to the Caballo Blanco Tuff, and the capping andesite flows are correlated to the andesite of Poverty Creek (Fig. 5).

Rhyolitic breccias are scarce and restricted to major fractures along the cauldron margin and intracaldera resurgent faults. They typically contain 1–2% phenocrysts of quartz, sanidine, and biotite in a vitroclastic matrix. The extrusive forms of rhyolite breccias are dikes or small plugs, which are emplaced within the volcaniclastics of the Hermosa region (moat deposits). The Mimbres Peak Formation of Jicha (1954) and Elston (1957) consists of rhyolite flows, domes, and epiclastics associated with the resurgence of the southern Emory cauldron. If the lakebeds are stratigraphically bracketed correctly at about 32 my (Axelrod 1975), then the reported age of 32.8 ± 1.0 my (Elston et al. 1973) for a rhyodacite dome in the Mimbres Peak Formation suggests the rhyolite breccias may be correlative to the rhyolite domes and breccias in the Mimbres Peak Formation.

Post-cauldron rocks

The four units to be described here are: (1) Caballo Blanco Rhyolite Tuff, (2) andesite of Poverty Creek, (3) rhyolite of Moccasin John area, and (4) rhyolite tuff of Diamond Creek.

In the study area, the Caballo Blanco Rhyolite Tuff of Elston (1957) is moderately welded, white to salmon, moderately to poorly pumiceous, and crystal-rich with 25–40% phenocrysts of quartz, sanidine, biotite, and plagioclase. The tuff is a sharp stratigraphic-marker bed that characteristically forms cliffs and unconformably overlies the volcaniclastics of the Hermosa region or andesite of Victoria Park Mountain to a thickness of about 100 m. A K–Ar age of 30.6 ± 0.8 my was assigned to the tuff by Elston et al. (1973). The source of the tuff remains unknown. However, recent paleomagnetic studies on the Kneeling Nun Tuff and Caballo Blanco Tuff suggest that the Emory centers may be the source for the Caballo Blanco Tuff (W. McIntosh oral comm. 1985). The name Caballo Blanco Tuff was extended to the northern Black Range by Abitz (1984) because it underlies the 28.3 my (age from Woodard 1982) andesite of Poverty Creek and resembles the type locality Caballo Blanco Tuff (Elston 1957) petrographically and chemically (Abitz 1984). Ericksen et al. (1970) extended the name into the central Black Range.

Elston et al. (1973) proposed the name andesite of Poverty Creek for basaltic-andesite and andesite flows exposed in Poverty Creek on the east side of the northern Black Range. In the study area, basaltic-andesite and andesite flows contain 5–10% phenocrysts of plagioclase, augite, and uncommon olivine and cap Caballo Blanco Tuff disconformably. The northeastern ring-fracture zone, along Circle Seven Creek, was the site of extensive extrusions. In this region a complete differentiated sequence is present. Rhyodacite flows conformably overlie andesite flows and contain 10–15% phenocrysts of plagioclase, quartz, and scarce biotite. When present, rhyolite flows cap rhyodacite flows and contain sparse phenocrysts of quartz, sanidine, and plagioclase. Near fissure vents the flows exceed 300 m in thickness, but commonly they are less than 200 m thick. Woodard (1982) reported a K–Ar age of 28.3 ± 0.6 my from a flow in the northern Black Range. The flows can be traced from their type locality to the central Black Range (Woodard 1982, Abitz 1984). The andesite of Poverty Creek is correlative to the andesite of Aspen Canyon of Ericksen et al. (1970) and the Alum Mountain Group of Farris (1981) because all these units lie unconformably over Caballo Blanco Tuff (Fig. 5). Seager et al. (1982) described a complex sequence of clastics, latite, andesite, and basaltic-andesite flows that lie above the Caballo Blanco Tuff. They reported their Bear Springs Basalt to be equivalent to the andesite of Poverty Creek, but other unit relationships are uncertain.

The rhyolite of the Moccasin John area was named by Ericksen et al. (1970) for the flow-and-dome complex present north of Circle Seven Creek surrounding Moccasin John Mountain. Recent field work has shown it to be equivalent to the rhyolite of Little Mineral Creek of Woodard (1982) and Abitz (1984), hence it is proposed that the name rhyolite of Little Mineral Creek be dropped. Ericksen et al. (1970) and Abitz (1984) incorrectly correlated the rhyolite of the Moccasin John area to the Mimbres Peak Formation. In the study area, discontinuous basal lithic tuffs contain abundant oxidized andesite fragments and overlie andesite of Poverty Creek with angular unconformity. Rhyolite flows and domes exhibit textural variations from spherulitic margins through vitrophyre to well-developed flow-banding. Sparse phenocrysts of quartz, sanidine, and biotite compose 2–4% of the rock. Extensive argillic alteration in the dome complex around Moccasin John Mountain suggests that hydrothermal systems are active. The flow-banded rhyolite of Rocky Canyon of Ericksen et al. (1970) and Farris (1981), and the flow-banded rhyolite within the rhyolite of Diamond Creek of Ericksen et al. (1970) are stratigraphically equivalent to the rhyolite of Moccasin John area because they both lie unconformably over the andesite of Poverty Creek and under the tuff of Diamond Creek. The correlation with the younger rhyolite of Seager et al. (1982) is uncertain.

A complex group of high-silica rhyolite tuffs is collectively referred to as the tuff of Diamond Creek. Cropping out along and west of the Continental Divide, a minimum of five cooling units have accumulated to a thickness greater than 300 m. Basal tuffs are generally crystal-poor (1–4%), pumiceous, and poorly welded, while upper bedded tuffs are crystal-rich (20–50%), moderately pumiceous, and moderately to densely welded. The phenocryst assemblage is always sanidine, quartz, and biotite. Along the northwest ring-fracture zone, Deadman Canyon cuts a prominent dike that is probably one of the vents for these tuffs. The dike cuts the volcaniclastics of the Hermosa region, the Caballo Blanco Tuff, and the andesite of Poverty Creek. Vertical flow foliation gives the dike the appearance of flow-banded rhyolite, which led Ericksen et al. (1970) to incorrectly place it with younger flow-banded rhyolites. The tuffaceous nature of the dike is evidenced by its broken phenocrysts and pumice. The tuff of Diamond Creek conformably overlies the rhyolite of the Moccasin John area and is equivalent to the tuffs within the rhyolite of Diamond Creek of Ericksen et al. (1970). It is also correlated to the tuff of Stiver Canyon of Woodard (1982), as used by Harrison (this guidebook), because tuff of Stiver Canyon also conformably overlies rhyolite of the Moccasin John area (Fig. 5).

Discussion

In addition to the porphyritic andesite of Curtis Canyon, several post-cauldron extrusion events delineate the northern ring-fracture zone. Rocks representative of these events are: (1) andesite of Victoria Park Mountain in the southeast, (2) andesite of Poverty Creek in the northeast, (3) rhyolite of Moccasin John area in the northeast, and (4) rhyolite tuff of Diamond Creek in the northwest. Of these, the porphyritic andesite of Curtis Canyon and the andesite of Victoria Park Mountain occupy the same time-stratigraphic position as southern ring-fracture extrusions. It is instructive to compare the two cauldron suites. Fig. 5 (columns II and IV) shows correlations for volcanic sections in the northern and southern parts of the Emory cauldron.

The intrusive–extrusive unit associated with the southern fracture zone is the Mimbres Peak Formation (Elston et al. 1975). The Mimbres Peak Formation consists of rhyolite flows, domes, and breccias with associated epiclastics. It is significant that voluminous rhyolite deposits of similar age are lacking in the northern fracture zone. However, local small rhyolite-breccia bodies do occur along the eastern fracture zone and principal resurgent faults, as discussed above. For the given temporal frame, volumetrically important northern ring-fracture rocks are andesites, while the southern time equivalents are rhyolites. It is suggested that these two distinct associations may reflect separate ring-fracture systems.

STRUCTURE

Ring-fracture system

The ring-fracture zone is defined by several features. First, a megabreccia zone, about 1 by 6 km, that lies to the south of Mud Spring and parallels the Mud Spring Canyon fault. Second, the existence of five intrusive–extrusive units, along sinuous fault traces, including: (1) porphyritic andesite of Curtis Canyon, (2) andesite of Victoria Park Mountain, (3) andesite of Poverty Creek and its differentiates, (4) rhyolite of the Moccasin John area, and (5) tuff of Diamond Creek. Third, the presence of outflow Kneeling Nun Tuff 4–8 km north, northeast, and east of the intracaldera Kneeling Nun Tuff. Finally, volcaniclastics of the Hermosa region (moat deposits) concentrically crop out around the intracaldera Kneeling Nun Tuff.

A broken net of scalloped fault slumps, considered to be the structural cauldron margin, can be traced over 180° arc that extends east–southeast from Diamond Peak in the north to south–southwest, east of Lake Mountain (Figs. 2, 6). Stratigraphic relationships indicate the fault motion is down to the outside of the structural margin, but poorly exposed fault planes dip toward the center of the cauldron at 79 to 67°. This geometry can be interpreted to represent reverse post-cauldron motion.

The most important part of this fault trace, in light of a double-cauldron hypothesis, is the northeast-trending section northwest of Victoria Park Mountain. This section of the structural margin separates the arcuate intrusion of the andesite of Victoria Park Mountain from the intracaldera Kneeling Nun Tuff. Although field work has not been completed south of Victoria Park Mountain, the geometry of the intrusion and the southward change in the structural-margin trend, from north to northeast (Fig. 6), suggest a septum region could be present.

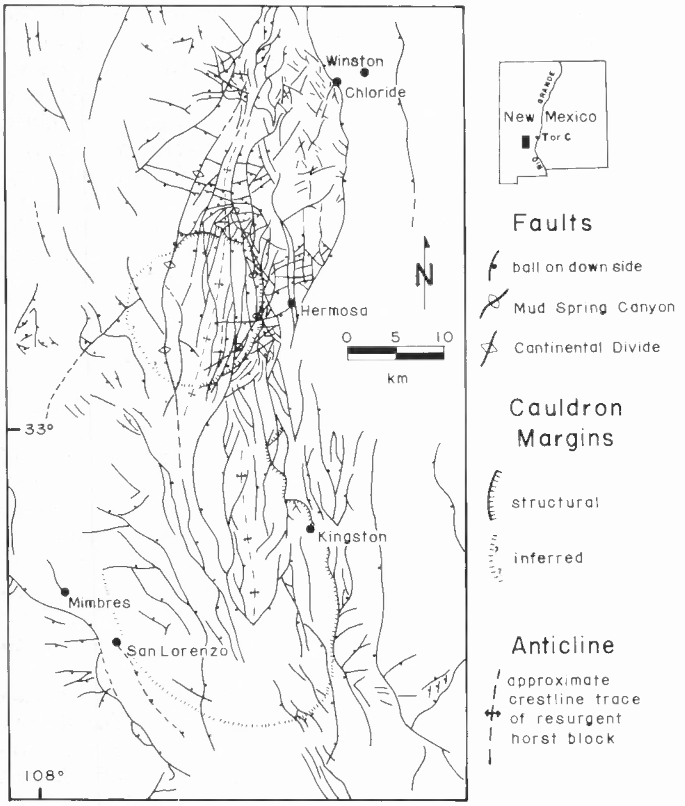

FIGURE 6—Tectonic sketch map of the Black Range. Hachures on northern structural-margin faults do not necessarily indicate downside. Compiled from Abitz (1984), Elston (1957), Ericksen et al. (1970), Farris (1980), Jicha (1954), Kuellmer (1954), Maxwell & Heyl (1976), Seager et al. (1982), Woodard (1982).

Horst-block system and resurgence

Trending about N10E, the resurgent horst block is bounded to the east by splays of the Mud Spring Canyon fault and to the west by splays of the Continental Divide fault. The north–northeast-trending fault planes dip 75–87° northwest or southeast and cut ring-fracture faults along the northern margin of the cauldron (Fig. 6). The axial trace of the anticlinal horst structure divides northwest-dipping strata along the Continental Divide from northeast-dipping strata east of the axis. The north-dipping nature of both limbs suggests a north-plunging structure. Dikes of rhyolite porphyry and breccia cut intracaldera Kneeling Nun Tuff and parallel both sides of the axial trace. These dikes are most abundant west of Victoria Park Mountain and are probably coeval with the rhyolite-breccia plugs emplaced along the Mud Spring Canyon fault because of their similar petrography.

Structural features that indicate a resurgent event are: (1) the anticlinal horst structure with paralleling rhyolite-breccia dikes, (2) reverse-fault geometry along the structural cauldron margin, and (3) an average 10° tilt difference between the volcaniclastics of the Hermosa region (moat deposits) and the overlying Caballo Blanco Tuff.

Resurgent events have been estimated to last on the order of 1,000–100,000 years (Smith & Bailey 1968). An estimate of the duration of resurgence in the northern Emory cauldron can be calculated with a simple model based on evidence found on the southern flanks of Lake Mountain. Here moat deposits dip 18–23° northeast, whereas the overlying Caballo Blanco Tuff dips 10–12° northeast. The difference in tilt (6–13°) is the assumed resurgent tilt, as the 30 my old Caballo Blanco Tuff was probably tilted by Basin and Range faulting (discussed below). For the case of a simple model based on a right triangle (Fig. 7), the resurgent tilt (O) is related to the radius of the cauldron (r) and height (h) of the apical resurgent block by $\tan O = h/r$. Approximate values for the northern Emory cauldron are $O = 10°$ (average value) and $r = 7.5$ km, which gives $h = 1.3$ km. A rapid magmatic resurgent rate of 0.01

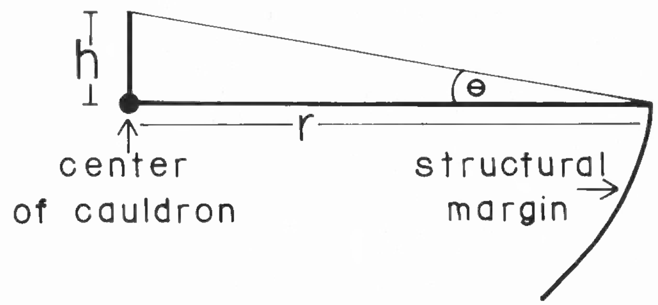

FIGURE 7—Geometric construction showing simplified relationships used in the estimation of the height of resurgence at center of cauldron for a given resurgent tilt at the structural margin.

m/yr (Savage & Clark 1982) divided into h yields a period of resurgence lasting 130,000 years. Since the given rate is too great for long-term regional deformation associated with resurgence due to detumescence (Marsh 1984), the 130,000 years must be considered a minimum. Considering the simplified assumptions, a resurgent period on the order of 100,000 years seems reasonable.

Basin and Range faulting

Basin and Range faulting in the Black Range is believed to have begun in the late Oligocene, because 29 my old andesites are found interbedded with extensive fanglomerates (W.R. Seager oral comm. 1986). It seems unlikely that new major fractures would form because of the availability of pre-existing resurgent and ring-fracture faults. For example, the Continental Divide fault follows the western-margin fault of the resurgent horst block, and the Mud Spring Canyon fault follows the eastern structural margin of the cauldron (Fig. 6). Thus, Basin and Range faulting continued to parallel the regional north–south structural fabric that had been previously defined by elongation of the Emory cauldron and anticlinal horst structure.

Present topography is the result of Basin and Range faulting. The Continental Divide fault is the westernmost range-bounding fault, crossing the Continental Divide between Diamond and Reeds Peaks. Eastward, the Mud Spring Canyon fault shows the largest apparent stratigraphic separation (about 150–200 m) and is probably the remaining principal fault in the study area along which much of the Basin and Range fault movement took place. The major fault boundary for the west side of the Winston graben lies just east of the Gila National Forest boundary at South Fork Palomas Creek. Reverse motion along the structural margins of the cauldron during Basin and Range and/or resurgent deformation is implied by the fault-plane geometry and juxtaposed stratigraphy. Reactivation of the resurgent faults has probably enhanced the anticlinal geometry centered on the horst block.

Discussion

At least three periods of deformation can be distinguished within the northern Emory cauldron: (1) collapse along the Mud Spring Canyon fault and associated ring-fractures; (2) resurgence along north-trending tensional fractures, probably reactivating collapse structures; and (3) Basin and Range faulting, probably along pre-existing north-trending structures. In addition, several east-trending faults cut the intracaldera Kneeling Nun Tuff between Cherry Mountain and Victoria Park Mountain. These east-trending faults are cut by north-trending Basin and Range faults, but cross-cutting relations are obscure with resurgent and ring-fracture faults.

CONCLUSIONS

Stratigraphic and structural evidence suggests that the Emory cauldron may be a double-cauldron complex. Stratigraphically equivalent ring-fracture intrusive–extrusive suites are andesitic in the north and rhyolitic in the south. The southward trace of the northern ring-fracture zone changes trend from north to northeast along Victoria Park Mountain, an arcuate andesite intrusion, and the resurgent horst block in the northern part of the Emory cauldron is west-stepped in relation to the southern resurgent block. A principal problem in the two-cauldron hypothesis is the petrographic similarity and the stratigraphic continuity of the Kneeling Nun Tuff throughout the complex. Radiometric dating and isotopic studies are currently being pursued in an attempt to prove, or disprove, the two-cauldron hypothesis.

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