



## ***Ash-flow tuffs and cauldrons in the northeast Mogollon-Datil volcanic field--A summary***

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1983, pp. 197-204. <https://doi.org/10.56577/FFC-34.197>

*in:*  
*Socorro Region II*, Chapin, C. E.; Callender, J. F.; [eds.], New Mexico Geological Society 34<sup>th</sup> Annual Fall Field Conference Guidebook, 344 p. <https://doi.org/10.56577/FFC-34>

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*This is one of many related papers that were included in the 1983 NMGS Fall Field Conference Guidebook.*

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# ASH-FLOW TUFFS AND CAULDRONS IN THE NORTHEAST MOGOLLON-DATIL VOLCANIC FIELD: A SUMMARY

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## INTRODUCTION

Eight regionally significant ash-flow tuffs are known in the northeast part of the Mogollon-Datil volcanic field (fig. 1). Each is sufficiently distinct petrographically and stratigraphically to suggest that it formed from a discrete eruptive episode. Most of the tuffs are of large volume (>100 km<sup>3</sup>) which implies cauldron collapse in their respective source areas during eruption. Of these eight tuffs, cauldrons are known in detail for two, known from reconnaissance for one, and a general area is suspected, but not proven, to contain cauldrons for two more. The general stratigraphic relationships of these ash-flow tuffs are described in Osburn and Chapin (1983). This paper will summarize two additional aspects of the ash-flow tuffs: (1) the petrologic characteristics which allow these tuffs to be definitively correlated from range to range, and (2) the known or hypothesized source cauldrons.

## ASHFLOW TUFFS

The three oldest ash-flow tuffs, the Datil Well, Rock House Canyon, and Blue Canyon Tuffs (fig. 1), are interbedded with the Spears Formation and are part of the Datil Group (new definition, see Osburn and Chapin, 1983). The five younger ash-flow tuffs, the Hells Mesa, La Jencia, Vicks Peak, Lemitar, and South Canyon Tuffs (fig. 1), are interbedded with lavas of the La Jara Peak Basaltic Andesite.

In addition to the eight units named above, two other ash-flow tuffs of moderate volume occur locally in the area. The oldest of these, the tuff of Granite Mountain (fig. 1), occurs sporadically in the top few tens of meters of the Spears Formation, often directly beneath the overlying Hells Mesa Tuff. This tuff closely resembles basal Hells Mesa Tuff but is clearly another unit where separated from the Hells Mesa by volcanoclastic rocks. The second unit, the tuff of Caronita Canyon, occurs mainly in the southern Magdalena Mountains within a moat-fill sequence of the Sawmill Canyon cauldron. However, this tuff has recently been found in the northern San Mateo Mountains farther to the west. This increased area of occurrence and consequent larger volume suggests that the Caronita Canyon might be a more regional unit than previously believed. Also present in several outcrop areas are small exposures of thin, probably local, ash-flow tuffs. These units will not be discussed further.

General petrologic characteristics of all the regional volcanic units in the northeast Mogollon-Datil volcanic field are included on New Mexico Bureau of Mines and Mineral Resources Stratigraphic Chart 1 (Osburn and Chapin, 1983). Data pertinent to regional ash-flow tuffs are summarized here in Table 1. Although the eight major ash-flow tuffs are fairly distinct, both texturally and petrographically, several of the units are similar enough to cause confusion if they occur in isolated outcrops. Among the phenocryst-poor units, the Rock House Canyon, La Jencia, and Vicks Peak Tuffs are quite similar in outcrop and hand sample. The Rock House Canyon can be distinguished petrographically by the presence of more plagioclase and less quartz. Stratigraphic position is the key discrimination tool for the other two units. Locally, subtle variations in pumice, lithophysae, and welding textures are use-

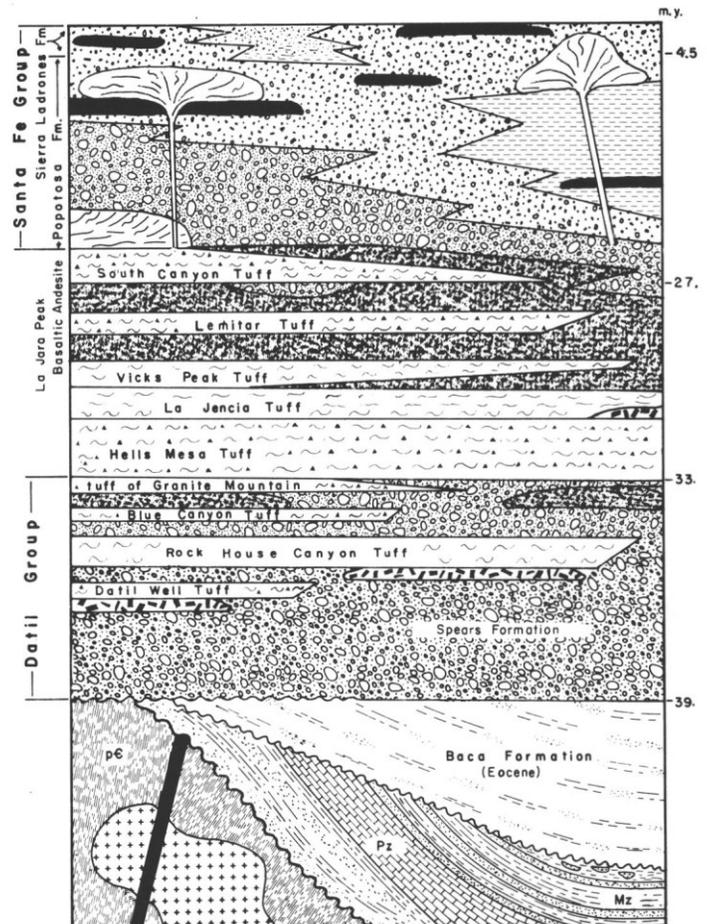


Figure 1. Composite stratigraphic column for the northeast Mogollon-Datil volcanic field. The base of the volcanic pile rests on rocks of Precambrian (pC), Paleozoic (Pz), Mesozoic (Mz), or Eocene age (Baca Fm) depending on geographic location relative to Laramide uplifts and basins. The Oligocene to Pleistocene section can be divided into three main parts: (1) Datil Group—volcanoclastic rocks of intermediate composition and interbedded felsic ash-flow tuffs and intermediate to mafic lava flows (39–33 m.y.); (2) a bimodal suite of rhyolitic ash-flow tuffs and basaltic-andesite lava flows (33–27 m.y.); and (3) Santa Fe Group—bolson sedimentary deposits and interbedded bimodal basaltic and rhyolitic rocks of Rio Grande rift (27–0.5 m.y.) with axial-river deposits of ancestral Rio Grande in upper part (4.5–0.5 m.y.). Patterns used on diagram are mostly self explanatory. Mafic lava flows are shown with black rectangles if plagioclase porphyritic; with gray cloth-like pattern if aphanitic (La Jara Peak type). Crystal-rich ash-flow tuffs shown with squiggly lines plus black triangles; crystal-poor ash-flow tuffs shown with squiggly lines only. Basalt flows in Santa Fe Group shown in solid black; rhyolites shown in white with flow lines.

*Table 1. Average modal phenocryst mineralogies for major ash-flow tuff sheets of the northeast Mogollon-Datil volcanic field. Abbreviation key: total phenocrysts (first column) divided into quartz (Q), sanidine (S), plagioclase (P), biotite (Bi), hornblende (Hb), and opaque minerals (Op, mainly iron-titanium oxides). Each mineral species listed by percent or as occurring in minor (m) or trace (tr) amounts. Trace minerals include sphene (s), zircon (z), clinopyroxene (cpx). Pumice are listed as sparse (sp), abundant (a), or very abundant (va). Zoned units divided into base (b), middle (m), and top (t).*

Unit	Phenocrysts								Pumice
	total	Q	S	P	Bi	Hb	Op	trace	
South Canyon (t)	15	7	8	tr	tr		m	s	a
(b)	3	1.5	1.5	tr	tr		m	s	a
Lemitar (t)	45	15	15	10	2	tr	m	s, z	sp
(m)	35	1.0	25	8	2		m	cpx	a
(b)	12	3.5	8	m	tr		m	s	a
Vicks Peak	5	m	4	tr	tr				m
La Jencia	5	m	4	tr	m		tr	cpx	sp-va
Hells Mesa (t)	50	15	25	10	1		m	cpx, s, z	
(b)	35	0.5	15	15	2-3	tr	>1.0	cpx	
Tuff of Granite Mt.	30	m	15	12	2	tr	m	cpx	a
Blue Canyon	17	tr	7	7	2	tr	m	cpx	sp
Rock House Canyon	5	tr	3	1	m		m	cpx	a
Datil Well Tuff	20	tr	15	tr	m		m	cpx	a

ful. Within the phenocryst-rich tuffs, all units are quite distinct except the upper Lemitar Tuff and the Hells Mesa Tuff which are indistinguishable in hand specimen or isolated outcrop.

One general petrologic change, based on abundance of quartz, allows the sequence of ash-flow tuffs to be split into quartz-poor (Datil Group) tuffs below and quartz-bearing to quartz-rich tuffs above (Hells Mesa and younger units). The quartz-bearing units also tend to be strongly zoned, both texturally and chemically. Two of the tuffs, the Hells Mesa and Lemitar Tuffs, show progressive changes up section from more mafic to more silicic composition. This is opposite the trend normally seen in ash-flow tuffs. Bornhorst (1980) has noted a general up-section increase in SiO<sub>2</sub> for the complete ash-flow tuff sequence. However, the entire group of ash-flow tuffs varies from rhyodacite to high-silica rhyolite and this compositional range is observed both above and below the Hells Mesa Tuff.

## CAULDRONS

Most major ash-flow tuffs are erupted from cauldrons which form as the erupting magma chamber is evacuated and its roof collapses during eruption (see Smith and Bailey, 1968). Young cauldrons, such as the Valles in northern New Mexico (Smith and others, 1970), are easy to define. As these features are eroded with passage of time and buried by younger units, they become progressively harder to recognize. In the Socorro-Magdalena area, some cauldrons are not only deeply buried but have been broken and extended by normal faulting, perhaps locally as much as 100 percent. At this stage of deformation, cauldrons can still be located but great caution must be exercised. The search no longer involves ring structures on space photos (the several such features observed in the Socorro area have no apparent relationship to the known cauldrons) or reconnaissance mapping of generalized composite stratigraphic units. The searching must instead be done through detailed geologic mapping and stratigraphic studies in which volcanic units are separated on a formation basis and mapped individually.

Two features of cauldrons make their recognition possible even after extreme deformation. First, the tuff within the cauldron is usually much thicker than its equivalent outflow sheet. Intracauldron thicknesses of greater than 1000 m are common. Second, a cauldron-fill or moat-fill

sequence is usually present between the cauldron-facies tuff and the next regional ash-flow sheet, indicating that a depression existed after the cauldron formed.

Preliminary reports on the Socorro area indicated the presence of as many as eight cauldrons within the area covered by this report (Chapin and others, 1978). Our present interpretation of the cauldrons in the Socorro-Magdalena area is shown on Figure 2. Only 5 cauldrons are now shown, as opposed to 8 in the 1978 version (increased data sorely restricts the number of possible interpretations). Of the 5 cauldrons shown, three (the Socorro, Sawmill Canyon, and Magdalena cauldrons) are well established by detailed mapping. These three cauldrons, shown with solid lines and dots, exhibit a markedly thickened cauldron-facies tuff and/or a thick cauldron-fill sequence. The remaining two cauldrons, shown with open circles, have been proposed by Deal (1973) and Deal and Rhodes (1976) on the basis of reconnaissance studies. Of these, the Nogal Canyon cauldron (3) is tentatively accepted unchanged, although little detailed work has been done in this area and the structure cannot be adequately evaluated until such work has been done. We now conclude that the Mount Withington cauldron (4) does not exist in its original form as defined by Deal (1973); however, at least one and possibly two cauldrons are thought to be present within this general area. Cauldrons have not been identified for any of the Datil Group ash-flow tuffs; therefore, the first cauldron discussed is the Socorro cauldron, source of the Hells Mesa Tuff.

## Socorro Cauldron

Two exposures of the topographic margin of the Socorro cauldron were the first cauldron-related features to be clearly recognized in the Socorro area. These two sites, at North Baldy in the Magdalena Mountains (Krewedl, 1974; Blakestad, 1978) and on Socorro Peak (Chamberlin, 1980, 1981) were initially described as segments of two different cauldrons. This separation was caused by miscorrelation of the cauldron-facies tuff in the Chupadera Mountains south of Socorro Peak with the younger Lemitar Tuff (Chamberlin, 1980, 1981). The cauldron-facies tuff at North Baldy was correctly called Hells Mesa. The correlations were finally resolved through mapping in the southeastern Magdalena Mountains (Osburn and others, 1981) and in the central Chupadera Mountains (Eggleston, 1982) where stratigraphic relations clearly identify the cauldron-facies unit as the Hells Mesa Tuff.

The Socorro cauldron is now well documented as the source of the widespread Hells Mesa Tuff (Eggleston, 1982). It was probably resurgent and its moat was filled with a variety of sedimentary and volcanic rocks which have been named the Luis Lopez Formation (Chamberlin, 1980; Osburn and Chapin, 1983). The Socorro cauldron is elongate east-west and has approximate dimensions of 22 km north-south by 35 km east-west. The east-west dimension has been lengthened considerably by late Cenozoic crustal extension. Cauldron-related rocks within the Socorro cauldron are now exposed over about 20-25 percent of the total area; approximately equal amounts of Hells Mesa Tuff and Luis Lopez Formation are exposed. The remaining 75 percent of the area is buried beneath younger volcanic units or basin fill. The margins of the Socorro cauldron are well-exposed at three widely separated localities (fig. 2): the southern Chupadera Mountains (SE), on Socorro Peak (NE), and at North Baldy in the Magdalena Mountains (NW). At all three locations, it is the topographic margin that is exposed with cauldron-related rocks overlapping an eroded cauldron-margin scarp, which had retreated considerably from the ring-fracture zone. In the Chupadera Mountains and on Socorro Peak, the ring-fracture zone is inferred from the location of rhyolite domes within the moat fill. In the west-tilted northern Magdalena Mountains, the ring fracture is exposed as the North

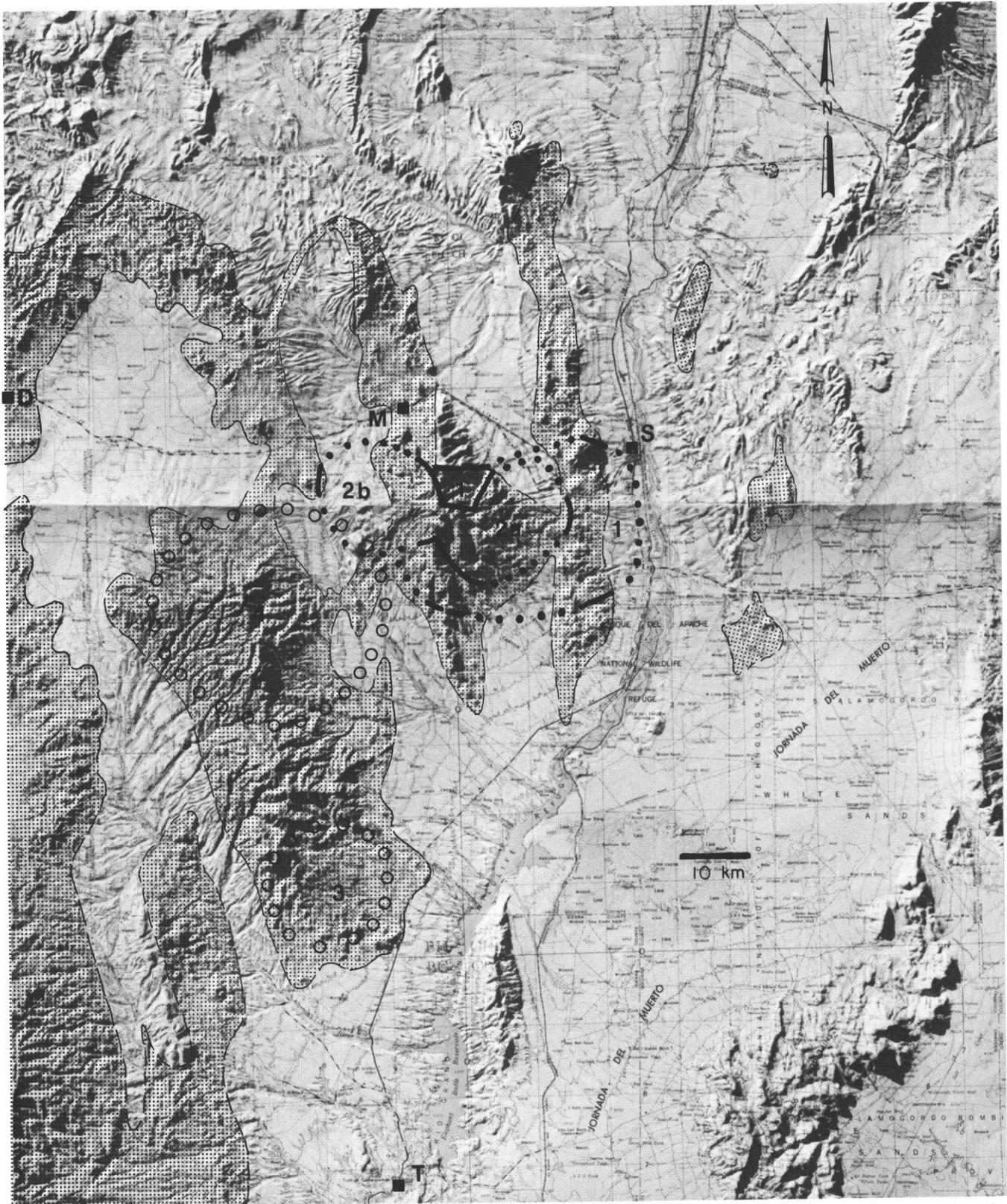


Figure 2. Cauldrons within the northeast Mogollon-Datil volcanic field. Base is composite of Socorro and Tularosa 2-degree quadrangles (Army Map Service plastic relief maps). From oldest to youngest, the cauldrons and their ash-flow tuff sheets are: (1) Socorro cauldron—Hells Mesa Tuff, (2a and 2b) Sawmill Canyon and Magdalena cauldrons—La Jencia Tuff, (3) Nogal Canyon cauldron—Vicks Peak Tuff. Sources for the Lemitar and South Canyon Tuffs have not yet been defined but may be within the area of the Mount Withington cauldron (4, Deal, 1973) which is now known to be younger and considerably more complex than was originally suggested (Osburn, 1983). Cauldrons shown with solid lines and dots have been defined from detailed mapping; those shown with boundaries of open dots are based on reconnaissance. Stippled areas show general areas where Oligocene volcanic rocks crop out. Solid squares and letters mark the towns of Datil (D), Magdalena (M), Socorro (S), and Truth or Consequences (T).

Fork Canyon fault zone (Krewedl, 1974; Sumner, 1980), an east-trending, near vertical, down-to-the-south group of faults separating thick cauldron-facies Hells Mesa on the south from Precambrian and Paleozoic rock on the north. Also within this area, due to the west-tilt of the northern Magdalena Range, a portion of the Precambrian and Paleozoic rocks within the floor of the Socorro cauldron is exposed. This area of exposed floor has been mapped by Krewedl (1974) but deserves a more detailed look now that the structural setting is understood. These pre-cauldron rocks are badly broken but appear not to be severely altered or stratigraphically disturbed. Mapping of the Socorro cauldron is complete except for a small part of the southwest quadrant which is known only from reconnaissance.

#### *Cauldron-facies Hells Mesa Tuff*

In most areas, the cauldron-facies Hells Mesa tuff is petrographically identical to the outflow sheet; that is, it is a crystal-rich (40-50%), quartz-rich (3-10%), quartz-latite to rhyolite ash-flow tuff. The cauldron-facies Hells Mesa is, however, much thicker, exceeding 1500 m in the Chupadera Mountains with no base exposed. Figure 3 compares outflow and intracauldron thickness. The base of the cauldron-facies Hells Mesa is observed only in the northwestern part of the cauldron in the Water Canyon area. Here, the quartz-poor more intermediate base of the unit is exposed beneath the quartz-rich upper interval. The intracauldron tuff is, therefore, reversely zoned from intermediate to felsic as is the outflow sheet.

In contrast to the outflow sheet, the lower three-fourths of the cauldron-facies Hells Mesa Tuff characteristically contains abundant lithic fragments. Whereas the outflow tuff normally contains only a few percent rock fragments, the cauldron-facies rocks commonly have 10-20 percent lithic fragments and more than 50 percent is not uncommon. Figure 3-23.6c (third day road log, this guidebook) illustrates the lithic-rich nature of the intracauldron Hells Mesa Tuff. The best exposures of cauldron-facies Hells Mesa are in the Chupadera Mountains within the area mapped by Eggleston (1982). Here, large zones of lithic breccias with little or no tuffaceous matrix are intercalated with more normal tuff containing disseminated lithic fragments. These lithic zones are

interpreted as breccia tongues that formed as the oversteepened cauldron wall collapsed during eruption (Eggleston, 1982). The lithologies present within these breccia tongues, and the fact that they thicken southward, suggest a source for the breccias on the southern rim of the cauldron (see fig. 3-10.8a, third day road log, this guidebook). Breccias are also present in the southeastern Magdalena Mountains but have not been mapped separately (Roth, 1980; Osburn and others, 1981). Collapse breccias are less abundant to absent in the exposures farther west in the western and north-central Magdalena Mountains. A possible interpretation of this distribution is that the northwestern part of the cauldron floor did not subside as rapidly or as far as did the remainder.

Within the southeastern third of the Socorro cauldron, the upper 100–200 m of cauldron-facies Hells Mesa Tuff contains few fragments of foreign rock materials but instead contains abundant fragments of rock very similar to the enclosing Hells Mesa Tuff. Figure 4 shows an outcrop of this rock type from the southeastern Magdalena Mountains. The fragments are usually redder than the enclosing tuff, vary from a few inches to a few feet in size, and apparently were never greatly vesiculated. Spherulites within the fragments are truncated at block boundaries and no shards or pumice are visible (Chamberlin, 1980). Also present at most outcrops of the breccias are interlayered finer grained, better sorted material interpreted as ash-fall layers (Eggleston, 1982). These deposits are thought to have formed during waning stages of the eruption by periodic blocking and clearing of a nearby vent. The pieces of the vent blockage (solidified Hells Mesa magma) were blown free but were too heavy to travel far in the ash flows and hence were deposited nearby within the cauldron. These deposits have been interpreted as co-ignimbrite lag-fall breccias by Chamberlin (1980) after a model by Wright and Walker (1977).

#### *Luis Lopez Formation*

As much as 1000 m of sedimentary and volcanic rocks buried the Hells Mesa Tuff in the topographic depression of the Socorro cauldron before the La Jencia Tuff, the next overlying regional ash-flow sheet, was emplaced. These rocks were named the Luis Lopez Formation by Chamberlin (1980). Even though he was mistaken about the age of the

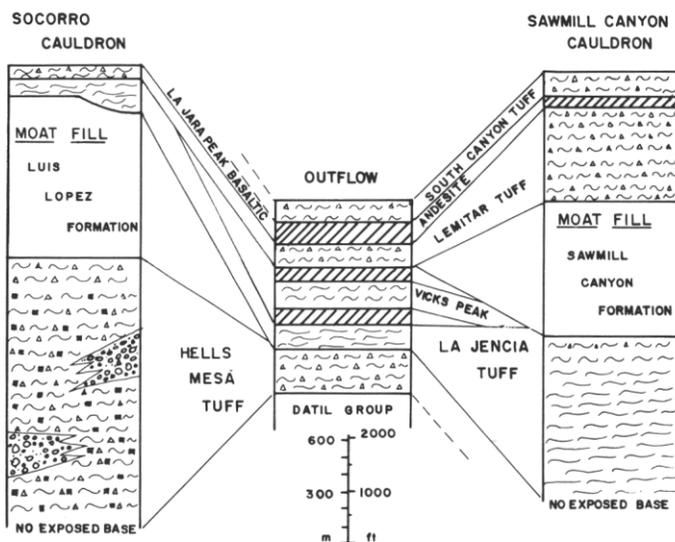


Figure 3. Diagram showing relative thicknesses of outflow and cauldron sequences for the Socorro and Sawmill Canyon cauldrons. Squiggly lines indicate ash-flow tuffs with the height of squiggle roughly indicating degree of pumice compaction. Triangles indicate abundance of phenocrysts and squares indicate lithic-rich units. Basaltic-andesite intervals are shown with diagonal lines. Thicknesses are averages from Osburn and Chapin (1983).



Figure 4. Co-ignimbrite lag-fall breccias containing red, Hells Mesa-like blocks within light-gray, quartz-rich upper Hells Mesa Tuff. Breccias of this sort, rhythmically interlayered with ash-flow layers (Eggleston, 1982), comprise the upper 100–200 m of the intracauldron Hells Mesa Tuff where exposed in eastern half of Socorro cauldron. Hammer for scale is approximately 33 cm long.

unit, this name has been retained because of excellent exposures and clear-cut stratigraphic relationships in the Chupadera Mountains (Osburn and Chapin, 1983).

Stratigraphic relationships show that the southern and southeastern portions of the Socorro cauldron were nearly full when the La Jencia Tuff filled the last remaining cauldron depression. Relationships are less clearly established elsewhere in the cauldron. In the southwestern part of the Socorro cauldron, no La Jencia Tuff is preserved above the moat deposits; in the northwestern part neither La Jencia nor Luis Lopez rocks are preserved. In the northeastern part of the cauldron, south of Socorro Peak, thick moat-fill deposits are present but no La Jencia Tuff is present to mark the upper limit of Luis Lopez deposits (Chamberlin, 1980). All the Oligocene post-Hells Mesa volcanic and volcanoclastic rocks in this area have been assigned to the Luis Lopez Formation, although some units may be younger than La Jencia Tuff. These units are locally overlain by small exposures of South Canyon Tuff (third regional ash-flow sheet above La Jencia Tuff).

Figure 5 diagrammatically depicts moat deposits of the Socorro cauldron along the north-south axis of the Chupadera Mountains. These deposits have been described in detail by Chamberlin (1980), Osburn and others (1981), and Eggleston (1982). A stratigraphically equivalent but somewhat different section of rocks, called the unit of Hardy Ridge has been described in the central Magdalena Mountains by Bowring (1980) and Roth (1980). These rocks are now considered part of the Luis Lopez Formation and the major unit in the central Magdalena Mountains is called the rhyolite of Hardy Ridge.

The Luis Lopez Formation consists of intermediate to mafic lavas; rhyolitic tuffs, lavas, and domes; and volcanoclastic sedimentary deposits. These rocks form a variable stratigraphic sequence in which the individual units interfinger complexly. The details of these interfingering relationships are not clearly known, or likely to be known, due to lack of exposure. The rhyolitic domes and lavas have been given names which are: the rhyolite of Cook Spring (NE), rhyolite of Bianchi Ranch (SE), and rhyolite of Hardy Ridge (SW). Other rock types have been referred to informally as lithologic members of the Luis Lopez Formation.

### Sawmill Canyon and Magdalena Cauldrons

Most of the western and central Socorro cauldron was obliterated by the next cauldron-forming event, eruption of La Jencia Tuff from the interconnected Sawmill Canyon and Magdalena cauldrons (2a and 2b, fig. 2). These two cauldrons are defined on very good evidence in the central part where they connect. Their outer extents to the east and west are inferred from relatively scanty data. Several workers have mapped part of this complex, including Allen (1979), Blakestad (1978), Bowring (20)

(1980), Donze (1980), Krewedl (1974), Osburn (1978), Petty (1979) Roth (1980), Simon (1973), and Wilkinson (1976).

Cauldron-facies La Jencia Tuff is stratigraphically higher than Hell! Mesa Tuff and is overlain by moat-fill deposits of Sawmill Canyon Formation which are in turn overlain by Lemitar Tuff. Therefore, collapse of the Sawmill Canyon and Magdalena cauldrons must postdate the Hells Mesa Tuff and predate the Lemitar Tuff. Within the northeastern Mogollon-Datil volcanic field, only the La Jencia and Vicks Peak Tuff occur in that interval. The Vicks Peak Tuff is thought to have erupted from the Nogal Canyon cauldron (3, fig. 2; Deal and Rhodes, 1976) therefore, both the Magdalena and Sawmill Canyon cauldrons are probably related to the La Jencia Tuff. In many outflow exposures of La Jencia Tuff, a distinct textural break and an increase in degree of welding occurs between a pumice- and crystal-poor lower interval and a slightly more crystal-rich, very pumiceous (lineated pumice) upper interval. This change in texture may mark the change from one source magma to the other; however, the relative order of eruption and collapse of the two cauldrons is as yet unknown.

Both the Sawmill Canyon and Magdalena cauldrons are about 15 km in diameter and approximately equidimensional, except where they join. The cauldron-margin exposures are mainly steep unconformities along topographic margins with a few minor exposures of reactivated rim fractures. The best exposures are within the central part of the complex mainly along South Canyon and Sawmill Canyon. The western margin of the Magdalena cauldron is placed between andesites inferred to be part of the Sawmill Canyon Formation and older rocks to the west. The eastern margin of the Sawmill Canyon cauldron is constrained by a core hole drilled at the Tower mine in the western Chupadera Mountains. Here, rhyolitic lavas similar to rocks within the Sawmill Canyon Formation underlie the Lemitar Tuff, whereas just a few hundred meters to the east, cauldron-facies Hells Mesa Tuff is exposed. The considerable stratigraphic offset between these two points is thought to be the result of the Sawmill Canyon cauldron margin (Chamberlin, 1981).

Between 700 and 1000 m of cauldron-facies La Jencia Tuff is exposed in the central Magdalena Mountains along Ryan Hill and Sawmill Canyon. All of these exposures of cauldron-facies La Jencia Tuff occur in the western part of the Sawmill Canyon cauldron; no cauldron-facies tuff is exposed within the Magdalena cauldron except for one small remnant preserved on the topographic rim in the northeastern part of the cauldron (along Patterson Canyon south of Magdalena).

The cauldron-facies La Jencia Tuff is overlain by as much as 650 m of local volcanic and volcanoclastic rocks found only within the cauldrons (fig. 3). These moat-fill deposits, named the Sawmill Canyon Formation (Osburn and Chapin, 1983a), occur extensively in the western half of the Sawmill Canyon cauldron and within the eastern third

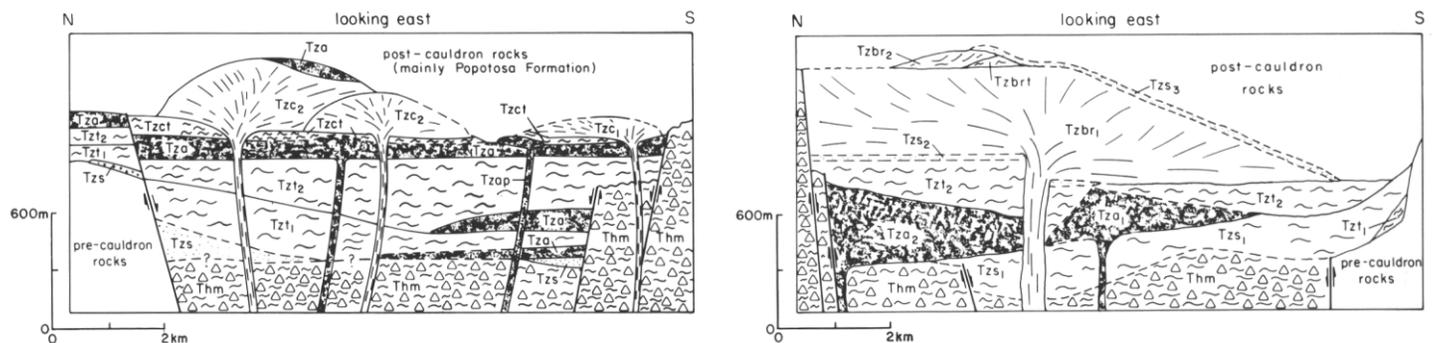


Figure 5. Diagrammatic cross section through the Socorro cauldron from north to south along the axis of Socorro and Chupadera Mountains. Northern half after Chamberlin (1980); southern half after Eggleston (1982). Tz designates Luis Lopez Formation within which Tza = andesitic lavas, Tzap = porphyritic andesite, Tzc(1,2,t) = rhyolite of Cook Spring, Tzbr(1,2,t) = rhyolite of Bianchi Ranch, Tzs = volcanoclastic sedimentary intervals, and Tzt = ash-flow tuffs, mainly crystal-poor, poorly welded and lithic-rich. Thm is the cauldron-facies Hells Mesa Tuff.

of the Magdalena cauldron. Scattered small outcrops of andesitic lavas within the western two-thirds of the Magdalena cauldron have been correlated with similar lavas in the Sawmill Canyon Formation. The next younger regional ash-flow tuff, the Vicks Peak Tuff, is not recognized in the area of these cauldrons. The second-younger ash-flow tuff, the Lemitar Tuff, overlies the moat fill within both the Magdalena and Sawmill Canyon cauldrons. Here, within the cauldrons, the Lemitar Tuff thickens from an average regional outflow thickness of 100-200 m to as much as 650 m. The thickness of this section of Lemitar Tuff suggests that the Sawmill Canyon and Magdalena cauldrons might have continued to subside during Lemitar eruptions or even that these cauldrons are also the source for the Lemitar Tuff. However, since very little, if any, post-Lemitar Tuff subsidence can be documented in the area (hence, no moat or moat fill), we believe that the Lemitar Tuff simply ponded in the remaining depression of the older cauldron.

### Cauldron-facies La Jencia Tuff

The cauldron-facies La Jencia Tuff crops out extensively only in Sawmill and Ryan Hill Canyons. Here, the minimum stratigraphic thickness of the unit is 700 to 1000 m (Bowring, 1980; Petty, 1979) and the base is not exposed. Throughout much of the lower part of the exposures, the rocks are uniform and relatively similar to outflow exposures of the La Jencia Tuff. Figure 6 illustrates the distinctive lineated and flow-banded fabric of the intracauldron La Jencia Tuff. The rock is typically densely welded and contains from 3-5 percent phenocrysts, mainly sanidine with minor quartz and biotite. Pumice is very abundant and conspicuously lineated. Near the top of the intracauldron section, welding becomes more variable and a local, crystal-rich upper layer is sometimes exposed which contains as much as 25 percent total phenocrysts, mainly sanidine with minor quartz. In addition, in Ryan Hill and southern Sawmill Canyon, a thin rhyolite lava flow is interbedded in the upper 100 m of the La Jencia Tuff. This flow may have been emplaced during a hiatus in the La Jencia eruption or, alternatively, may mark the boundary between La Jencia Tuff and unrecognized Vicks



Figure 6. Lineated pumice in cauldron-facies La Jencia Tuff. This photogenic block is from Sawmill Canyon in the Magdalena Mountains (sec. 32, T4S, R3W, unsurveyed). The upper surface of the block, broken parallel to the flow direction, shows extremely elongate pumice; whereas, the front surface, broken perpendicular to the flow direction, shows that the pumice in cross section are narrow, flattened lenses. The elongation is thought to develop as exceptionally hot pumice agglutinates and stretches during the final stages of deposition. Lineated pumice such as these show the direction of movement at the moment of deposition and have been used to successfully predict source areas and paleodrainage systems (Deal, 1973; Chapin and Lowell, 1979). Note the lack of lithic fragments and the scarcity of phenocrysts in comparison to the Hells Mesa Tuff (fig. 3-23.6c, third day road log, this guidebook). The width of the block is about 22 cm.

Peak Tuff. The intracauldron La Jencia Tuff, in contrast to the intracauldron Hells Mesa Tuff, is typically lithic poor and contains few lithic-rich zones. It does, however, contain several large exotic blocks, the largest of which is about 300 m long. These blocks, consisting of andesitic lavas, rhyolitic tuffs and sandstones, probably slid off the southwestern cauldron margin during the eruption. These lithologies are similar to rocks in the Luis Lopez Formation which probably occupied most of the cauldron margin at this time.

### Sawmill Canyon Formation

As much as 650 m of rhyolitic lavas and tuffs, mafic lavas, and volcanoclastic rocks overlie the La Jencia Tuff in the western one-half of the Sawmill Canyon cauldron. Only mafic to intermediate lavas and andesite-rich volcanoclastic rocks have been reported in the Magdalena cauldron. Within the Sawmill Canyon cauldron, the entire Sawmill Canyon Formation is exposed only along Sawmill and Ryan Hill Canyons. Within these canyons the unit consists dominantly of andesitic lavas and volcanoclastic sedimentary rocks on the north and rhyolitic lavas and tuffs toward the south. The top 100-200 m of this sequence of rocks is exposed in several smaller outcrop areas farther east. One moderately voluminous ash-flow tuff from near the top of the Sawmill Canyon Formation, the tuff of Caronita Canyon, has been named separately, all other units are designated lithologically as informal members of the Sawmill Canyon Formation. Figure 7 shows a generalized north-south cross section along the east wall of Sawmill Canyon.

Exposures of cauldron-fill deposits are much less abundant in the Magdalena cauldron than in the Sawmill Canyon cauldron. Here, exposures are limited to a thin sliver along the eastern side of the cauldron (Allen, 1979) and to relatively small exposures of the upper part of the section farther west at Cat Mountain (Wilkinson, 1976) and Landavaso Reservoir (Simon, 1973). No extrusive rock types besides andesitic lavas and andesite-dominated volcanoclastic rocks are reported in these exposures. Minor quartz-eye porphyry intrusions are present near the south end of the eastern exposures (Allen, 1979); however, these intrusions have not been clearly linked in age to the Magdalena cauldron. The Lemitar Tuff overlies the Sawmill Canyon Formation and marks its upper limit.

### Nogal Canyon Cauldron

The next younger regional ash-flow tuff, the Vicks Peak Tuff, was apparently erupted from the Nogal Canyon cauldron in the southeastern San Mateo Mountains. This cauldron has been proposed by Deal and Rhodes (1976) based on reconnaissance and reinterpretation of maps

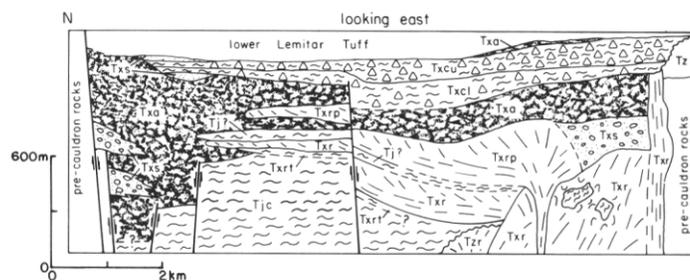


Figure 7. Diagrammatic north-south cross section through Sawmill Canyon cauldron along Sawmill Canyon (after Bowring, 1980; Roth, 1980). Tjc designates cauldron-facies La Jencia Tuff. Tx designates the Sawmill Canyon Formation within which Txa = andesitic lavas and andesitic volcanoclastic rocks, Txc(1,u) = tuff of Caronita Canyon, Txr and Txrp are crystal-poor and sanidine-porphyrific rhyolite lavas and intrusions, Txrt = local tuffs associated with rhyolitic intrusions, Txs = volcanoclastic conglomerates and sandstones. Tz is the older Luis Lopez Formation exposed on the cauldron rim.

by Farkas (1969) and Furlow (1965). The major evidence for this cauldron is the great thickness of Vicks Peak Tuff (>650 m), a group of small stocks along the proposed southern cauldron margin, and thick post-Vicks Peak rhyolites in the northwestern part of the cauldron. Foruria (in preparation) has recently mapped a 6x 16 km north-south strip just east of Vicks Peak within the Nogal Canyon cauldron. Within Foruria's map area, the base of the Vicks Peak is well exposed and small areas of overlying rhyolitic lavas are present. This mapping supports a thickness of about 650 m for the Vicks Peak Tuff. Again, these data allow, but do not demand, the presence of a cauldron. We are tentatively recognizing the Nogal Canyon cauldron as the probable source of the Vicks Peak Tuff but recommending caution in its usage. Little detailed mapping has been done either within the Nogal Canyon cauldron or in the high country of the southern San Mateo Mountains where large thicknesses of Vicks Peak-like tuff and overlying silicic lavas have been noted during reconnaissance traverses.

### Mount Withington Cauldron

Sources are not definitely known for the two youngest ash-flow tuff sheets, the Lemitar and South Canyon Tuffs. A probable area for their sources is in the northern San Mateo Mountains within an area mapped by Deal (1973). Here Deal proposed a large resurgent cauldron (4, fig. 2) and suggested that it was the source for the A-L Peak Tuff (now called La Jencia Tuff and Vicks Peak Tuff). We discovered, however, that the rocks at Deal's type section on A-L Peak did not have the same mineralogy as the outflow sheets with which he had correlated them. During preparation of Stratigraphic Chart 1 (Osburn and Chapin, 1983), extensive reconnaissance was done in an attempt to correlate the stratigraphy of the Magdalena, Bear, and Gallinas Mountains with the rocks in the San Mateo and Datil Mountains. This reconnaissance supported Deal's interpretation of more than 1000 m of cauldron-facies(?) tuff in the core of the northern San Mateo Mountains, but indicated that the rocks on A-L Peak were higher stratigraphically than the outflow sheets with which they had been correlated. The term A-L Peak Tuff was, therefore, abandoned. In an attempt to clarify the situation, the Monica Saddle quadrangle (northwest corner of the San Mateo Range) was mapped in detail during the summer of 1982 (Osburn, 1983) and an area in East Red Canyon (east-central San Mateo Range) is being mapped during the current field season. In addition, Atwood (1982) has mapped an area around San Juan Peak just to the southeast of Deal's cauldron.

Mapping by Osburn (1983) clearly shows that the rocks on A-L Peak are younger than Lemitar Tuff and probably correlative with the South Canyon Tuff. Two tuffs with South Canyon petrographic characteristics are present in the eastern San Mateo Mountains (Donze, 1980). Our present interpretation is that the thick unit on A-L Peak is South Canyon Tuff and that the upper, thinner unit is a local ash-flow tuff. This mapping further shows that a large area of rocks in the northwest part of Deal's cauldron are older than the cauldron-facies South Canyon Tuff on A-L Peak and that these rocks are Hells Mesa Tuff, La Jencia Tuff, and Lemitar Tuff. In this area, the Vicks Peak Tuff is absent and its stratigraphic position is occupied by a thick, high-fluorine, pseudobrookite-bearing rhyolite lava flow. Atwood (1982) shows the presence of outflow sheets of Hells Mesa, La Jencia, and Vicks Peak Tuffs in the east-central San Mateo Mountains. Reconnaissance west of Atwood's area in east Red Canyon, within Deal's Mount Withington cauldron, also shows the presence of these relatively thin outflow units as well as the overlying Lemitar Tuff. The presence of these large areas of outflow units within the proposed Mount Withington cauldron clearly indicates that this structure is inadequately defined and that any cauldrons present must be much smaller than previously suggested. The presence of a cauldron or cauldrons in the northern San Mateo Range is considered very probable by us because of the great thickness of South Canyon

Tuff in the north-central part of the range. This great thickness of ash-flow tuff must have accumulated during eruption in a subsiding cauldron or in a nearby, slightly older, preexisting cauldron. Projects currently in progress should locate and delineate these cauldrons within the next few years.

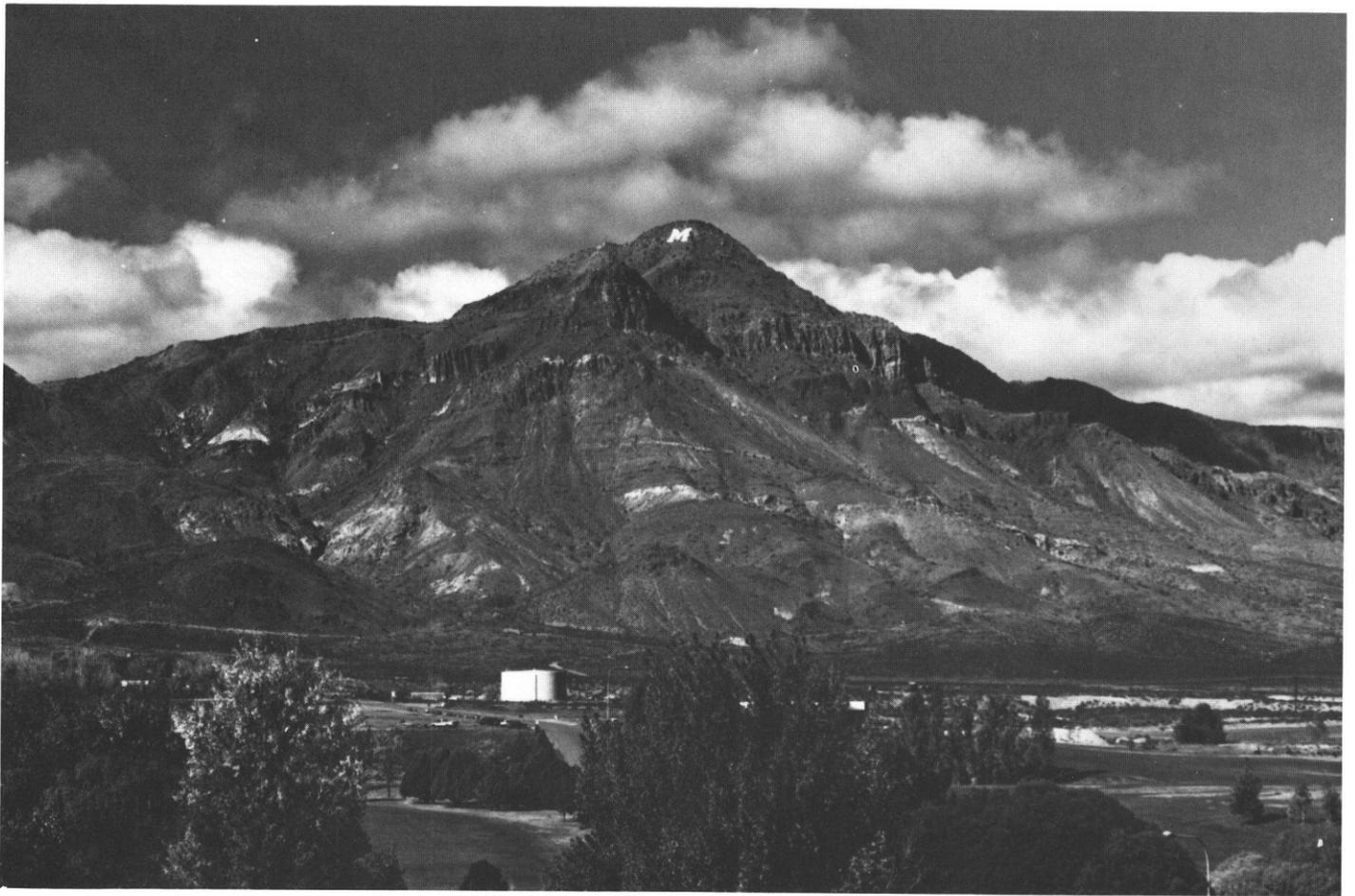
### ACKNOWLEDGMENTS

As with any summary paper, the basic work in this paper has been done by many workers. A complete list of these mapping projects is included in Osburn and Chapin (1983). This manuscript has benefited substantially from critical readings by T. L. Eggleston and R. M. Chamberlin.

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*Socorro Peak from the New Mexico Tech campus, 1979. The northern topographic margin of Socorro cauldron (Oligocene) truncates well-stratified limestones and shales of Pennsylvanian age near center of photograph. The topographic margin is overlapped and buried by moat deposits of Luis Lopez Formation (Oligocene) and rhyolitic domes and flows of Socorro Peak Rhyolite (late Miocene). Photo by Bob Osburn.*