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Geologic Map 68

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Geology of Lion Mountain and northern Arrowhead Well quadrangles, Socorro County, New Mexico

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INTRODUCTION

The Lion Mountain map area comprises the entire Lion Mountain quadrangle and the northern third of the adjacent Arrowhead Well quadrangle. This area mainly occupies the slope between the Gallinas Mountains on the east and the White Lake section of the Plains of San Agustin on the west. Fig. 1 illustrates the location of this area in Socorro County, New Mexico. Lion Mountain is a large and prominent landform (see Fig. 2); otherwise the area consists of low hills separated by alluvial slopes covered with eolian sand. All of the map area falls within land controlled by the HH Ranch (northern part) or the Montosa Cattle Company (southern part); the foremen of these ranches should be consulted for permission before entering. Fair access is provided by the North Lake Road, which extends northwest from US–60, and by numerous woodcutters' roads within the areas of Cibola National Forest. Deep sand makes 4-wheel drive advisable on many of these roads.

Geologically, much of the area is dominated by the White Lake basin (Weber, 1980, 1982). Piedmont-slope deposits around the margins are graded toward the basin, which contains lacustrine deposits in the lower parts. Eolian sand, derived largely from the lake beds, mantles large areas of the eastward side of the basin. R. H. Weber, retired from the New Mexico Bureau of Mines and Mineral Resources, is currently completing a regional study of shorelines and lacustrine deposits of Lake San Agustin. His work provided the basis for delineating the features shown on the western section of the map.

Previous geologic studies in the area surrounding the Lion Mountain quadrangle include two published reconnaissance maps (Willard and Givens, 1958; Givens, 1957) and several, more detailed but unpublished, maps in theses. The reconnaissance mapping was of limited use in preparing this map because of changes in the method for dividing volcanic rocks into stratigraphic units. Studies in adjacent areas that were of particular importance to this project are theses by Chamberlin (1974) and Laroche (1980) in the central and northern parts of the Gallinas Peak quadrangle, respectively, and Harrison (1980) and Coffin (1981) in the

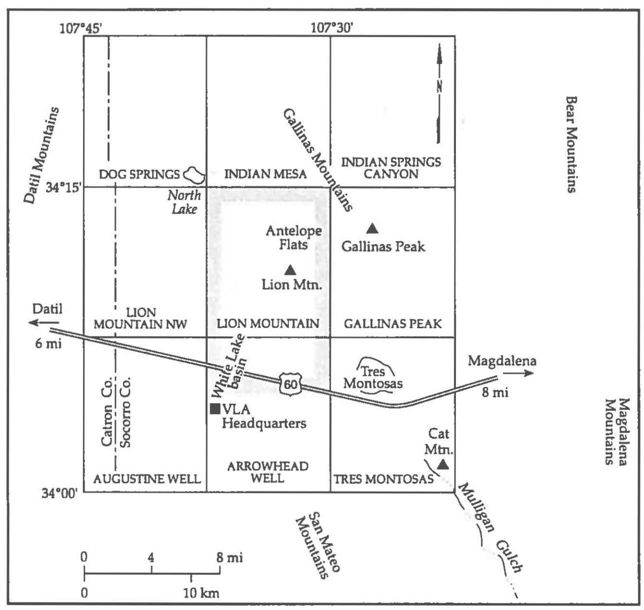


FIGURE 1—Index map of Lion Mountain area showing the Lion Mountain quadrangle and northern third of the Arrowhead Well quadrangle that are included in this study, surrounding quadrangles, major geologic and geographic features, and highway access.

Dog Springs quadrangle northwest of this map area. Givens (1957) provides the only mapping of the area due north of the Lion Mountain quadrangle. These earlier studies are detailed in Osburn and Chapin (1983a). Only mapping by Osburn, Laroche (1980), and Weber was used in compiling the geology of the Lion Mountain and northern Arrowhead Well quadrangles. Generalized boundaries for Quaternary units in the eastern part of the study area were mapped from aerial photographs or from estimations or were modified after soil mapping by the U.S. Soil Conservation Service (Job 35902, sheet 44). A soil survey of Socorro County subsequently has been published (Johnson, 1988). L. D.

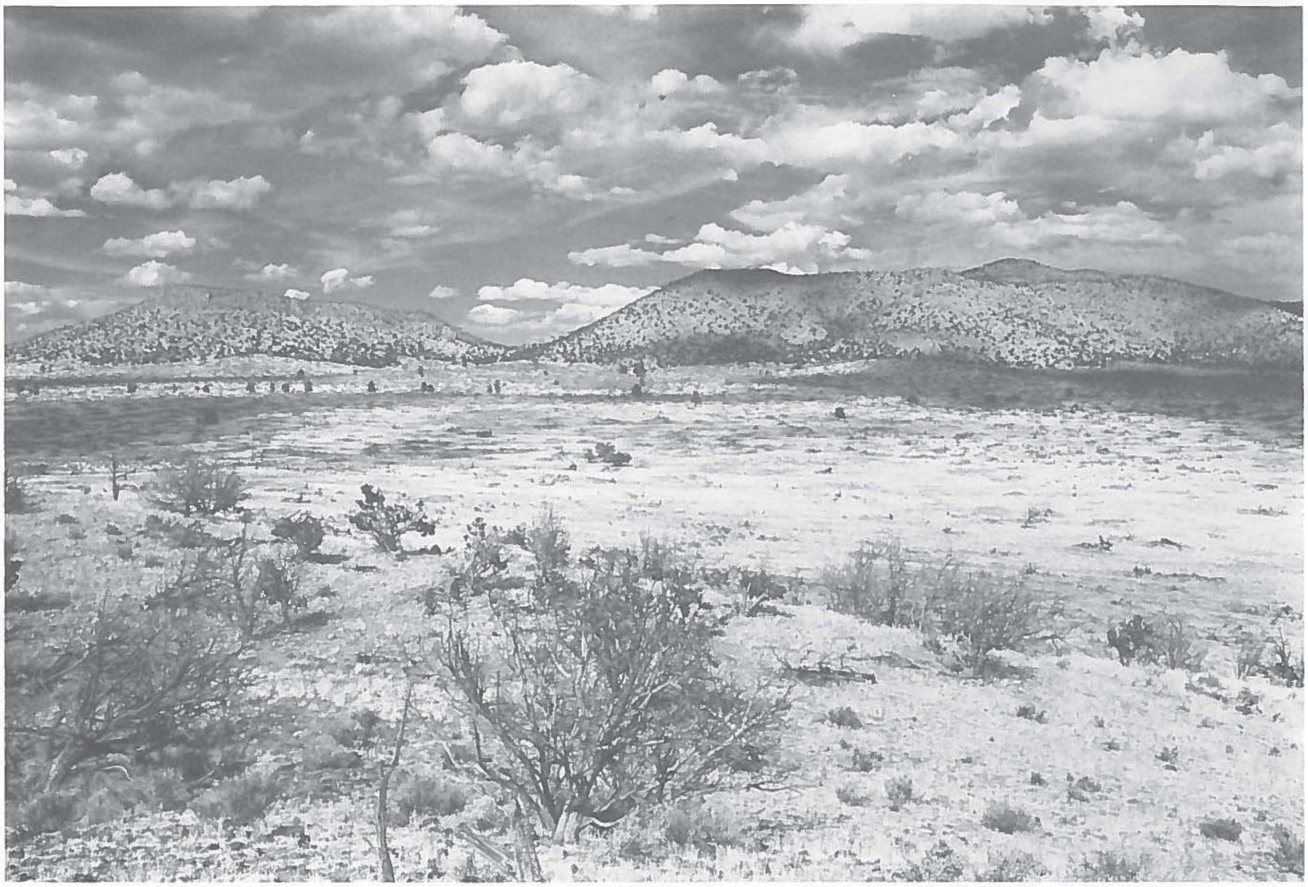


FIGURE 2—Vista of Lion Mountain from the southwest. Foreground is a small hill made up of the andesite of Lion Mountain overlying the South Canyon Tuff. Piedmont deposits, largely covered by eolian sand, separate this hill from the main mass of Lion Mountain. On Lion Mountain, the northern mesa is composed entirely of South Canyon Tuff. The gentle slopes are underlain by the crystal-poor lower interval, and the cliffs are composed of the more crystal-rich upper interval. The lower interval is less resistant to erosion in spite of being more densely welded than the upper interval, perhaps because it is more intensely jointed. The South Canyon Tuff dips slightly to the south and forms the lower slopes of the southern hills; the tops of these hills are made up of the andesite of Lion Mountain.

McFadden of the University of New Mexico directed soil-geomorphic studies in the northeastern Plains of San Agustin that established a soil-based Quaternary chronology (Ritter et al., 1984) and defined the amounts, timing, and rates of Quaternary displacement along the VLA fault (Menges et al., 1984).

Several well-known Indian ruins, such as those at Gallinas Springs, are present in the area around the Lion Mountain quadrangle. During this study many other sites and randomly distributed tools were seen. Most of these sites are small, consisting of the rubble of from one- to three-room rock houses, and widely spaced, as if the population were dispersed rather than communal. Most of the sites are located on the northeast sides of hills in positions protected from the southwest wind. Larger building sites consisting of from five to 15 rooms were seen in at least two places. All of the ruins are in the eastern half of the Lion Mountain quadrangle, as far west as the east side of Lion Mountain, and in the western half of the adjoining Gallinas Peak quadrangle. If more than a few of these were occupied at any given time, a considerable population is indicated. A wetter climate at the time of occupation could have supported a fairly large population. Alternatively, in a climate similar to today's, the Indians may have used well-developed dry-land farming techniques. No natural water sources sufficient for irrigation were seen.

Ruin locations were recorded on field sheets but were not compiled onto the final map to prevent site destruction. These site locations can be provided by the senior author for legitimate archeological studies.

ACKNOWLEDGMENTS—The authors are indebted to several people whose efforts and support have greatly improved this publication. We owe a major debt to the many workers who established the stratigraphic base that made this mapping much easier, particularly to C. E. Chapin who directed most of the stratigraphic studies. Individual studies and workers are detailed in Osburn and Chapin (1983a). We would like to thank Johnny McKinley and Pete Evans for allowing us access to the private land of the HH Ranch and the Montosa Cattle Company, respectively. The New Mexico Bureau of Mines and Mineral Resources financially supported this mapping. Ralph Johnson of the U.S. Soil Conservation Service provided copies of soil maps for the area. Reviews by W. R. Seager, R. M. Chamberlin, and J. W. Hawley substantially improved the text.

STRATIGRAPHY

All pre-Quaternary rocks exposed within the Lion Mountain map area are Tertiary volcanic or volcaniclastic rocks. Most of the volcanic rocks exposed here are ash-flow tuffs of regional extent and lava flows from local vent areas. The regional units are described by Osburn and Chapin (1983a). A brief lithologic summary of each is given here and on the map.

Spears Formation of the Datil Group

The oldest rocks exposed in this quadrangle are andesitic lavas and breccias of the upper member of the Spears Formation (*Tsu*); they cover approximately 1/4 mi^2 in the northeast corner of the quadrangle. Outside this quadrangle, the Spears Formation also includes volcaniclastic sedimentary rocks and mudflow breccias and interfingers with separately named regional ash-flow tuffs. Collectively this sequence is termed the Datil Group (*Td*; see Osburn and Chapin, 1983a).

Immediately to the east in the Gallinas Peak quadrangle, the complete thickness of the Datil Group is exposed (Laroche, 1980). There the section comprises a lower volcaniclastic member 1,100 ft (340 m) thick (lower member of the Spears Formation), the medial Rock House Canyon Tuff 0–300 ft (0–90 m) thick, and an upper sequence of pyroxene-porphyritic andesitic lavas 0–560 ft (0–170 m) thick (upper member of the Spears Formation). Exposures in the Lion Mountain quadrangle consist entirely of the upper andesitic lava sequence. This interval is as much as 560 ft (170 m) thick 2 mi (3 km) to the northeast of the Lion Mountain quadrangle, but thicknesses vary considerably within the area of exposure. In some places the upper andesitic lava is absent, and the Hells Mesa Tuff rests on the Rock House Canyon Tuff. Within this map area the interval is at least 200 ft (60 m) thick.

The andesitic lavas have a distinct chocolate-chip texture because the matrix of uniform, fine-grained, grayish plagioclase and ferromagnesian microlites and glass is punctuated with dark-colored clinopyroxene and orthopyroxene phenocrysts that average 5–6 mm in length. These large pyroxene phenocrysts, which reach lengths as great as 1.4 cm, account for 2% of the andesitic lavas. Smaller clinopyroxene phenocrysts, averaging 0.1–0.2 mm in size, comprise as much as 10% of the lavas. Clear to white plagioclase phenocrysts (An63), as long as 2 mm but averaging 0.5–0.6 mm in length, make up as much as 25% of the rock (Laroche, 1980). Minor monolithic breccias are present locally at flow boundaries as are thin lenses of coarse heterolithic volcaniclastic sediments.

The Datil Group is regionally overlain by a sequence of five widespread ash-flow tuffs, which are, from oldest to youngest, Hells Mesa Tuff, La Jencia Tuff, Vicks Peak Tuff, Lemitar Tuff, and South Canyon Tuff (see Osburn and Chapin, 1983a). Four of these five units crop out within the Lion Mountain quadrangle; the Lemitar Tuff is not present.

Hells Mesa Tuff

The Hells Mesa Tuff (*Thm*) is the oldest regional ash-flow tuff exposed within the Lion Mountain quadrangle. It crops out in a band along the northern edge of the quadrangle and in a few small areas of poor exposure in the center of the map area just northwest of Lion Mountain. The Hells Mesa Tuff was erupted from the Socorro cauldron in the Chupadera and Magdalena Mountains (Osburn and Chapin, 1983b) and is present throughout much of the area from Socorro to Datil as a thick prominent unit. Within the Lion Mountain quadrangle, the Hells Mesa is densely welded and fairly thick. About 500 ft (150 m) are present in the northeast corner of the map, where both base and top are exposed. The Hells Mesa typically crops out as steep rubble-covered slopes.

The basal part of the Hells Mesa Tuff commonly contains about 25% phenocrysts of subequal amounts of plagioclase and sanidine, 2–3% biotite, and minor quartz and hornblende (Laroche, 1980). A few tens of feet higher in this unit, quartz and sanidine abruptly increase in relative abundance as plagioclase and biotite decrease. At this transition, total phenocryst content increases to 40–50%. Chemical composition also changes upward from rhyodacitic to rhyolitic (Eggleston et al., 1983); however, this chemical transition occurs near the middle of the unit, considerably higher stratigraphically than the mineralogical change. The phenocryst-rich Hells Mesa Tuff is overlain by the phenocryst-poor La Jencia and Vicks Peak Tuffs.

La Jencia Tuff

The La Jencia Tuff (*Tj*) is also a major regional unit. It crops out extensively in the Bear, Gallinas, and Datil Mountains surrounding this map area and in the San Mateo Mountains south of the Plains of San Agustin. The Lion Mountain quadrangle lies between an area of thick exposures to the southeast and thinner, less continuous outcrops to the northwest. The La Jencia is thick, densely welded, and commonly lineated in the eastern exposures. To the northwest it becomes thinner and commonly contains at least one welding break. Within this map area, the La Jencia Tuff crops out extensively in the northeast quadrant and as one small exposure in the northeastern corner of the Arrowhead Well quadrangle.

The La Jencia Tuff within the map area typically is densely welded and contains strongly lineated pumice. The directions of lineation commonly trend northwest–southeast, in line with the source cauldron in the Magdalena Mountains (Osburn and Chapin, 1983a). Locally, rocks with extremely flattened and lineated pumice are altered by vapor-phase activity to a soft and punky texture. The La Jencia also commonly includes lithophysal zones containing vapor-phase minerals, such as hematite and pseudobrookite (Fe_2TiO_5).

The La Jencia Tuff typically contains 3–7% tabular sanidine phenocrysts and minor amounts of quartz, biotite, and, near the top, green clinopyroxene. Phenocryst content and the relative abundance of biotite increase upward. The La Jencia is chemically zoned upward from rhyolitic to rhyodacitic (Kedzie, 1984). The La Jencia Tuff is overlain by the petrographically similar Vicks Peak Tuff.

Vicks Peak Tuff and unnamed sedimentary rocks

The Vicks Peak Tuff (*Tvp*), formerly called the pinnacles member of the A–L Peak Tuff (see Osburn and Chapin, 1983a), crops out extensively throughout the area. It was erupted from the Vicks Peak area of the southern San Mateo Mountains (Hermann, 1987). Within the Lion Mountain quadrangle the Vicks Peak Tuff crops out along the eastern edge and in the very northwest corner.

The Vicks Peak Tuff is normally separated from the underlying La Jencia Tuff by a welding break; however, in the north-central part of the map area, a 20-ft-thick (6-m-thick), poorly exposed, conglomeratic interval (*Tvs1*) separates the two units. Float in this interval consists of rounded fragments of Hells Mesa Tuff, La Jencia Tuff, and rhyolite lava. The location of this sedimentary unit next to a fault suggests deposition in an Oligocene strike valley. The sediments may therefore record the onset of extensional faulting in this area.

Northwest of the Lion Mountain quadrangle, the basal Vicks Peak Tuff lies along an erosional unconformity on rocks as old as the upper Spears Formation (Harrison, 1980; Coffin, 1981); many exposures are in paleovalleys. In the northwest corner of the Lion Mountain quadrangle, the basal contact of the Vicks Peak is irregular and has at least 100 ft (30 m) of relief, suggesting that here too paleotopography was present.

The Vicks Peak Tuff and underlying La Jencia Tuff are quite similar petrographically but can be distinguished by texture. The Vicks Peak Tuff, like the La Jencia, contains a small percentage of sanidine phenocrysts and traces of quartz, biotite, and pyroxene. Trace amounts of amphibole, not commonly present in the La Jencia Tuff, are seen in some thin sections of the Vicks Peak Tuff (Laroche, 1980). The basal Vicks Peak has fewer phenocrysts than the basal La Jencia. Phenocryst content increases upward in the Vicks Peak Tuff from less than 1% to about 7%, and silica content decreases upward in a normally zoned manner (Kedzie, 1984). The Vicks Peak Tuff is commonly gray with white or white-rimmed pumice, whereas the La Jencia is commonly shades of light brown or pink. Whereas the La Jencia Tuff has strongly lineated pumice, the Vicks Peak Tuff rarely has lineated pumice in the map area, although such lineations are present farther south in the Magdalena and San Mateo Mountains. Basal Vicks Peak contains less pumice than the basal La Jencia Tuff, and Vicks Peak pumice commonly is less compacted and contains large, sometimes amethystine, vapor-phase quartz grains.

Rhyolite of Piñon Well

The rhyolite of Piñon well (*Tpw*), informally named for exposures near Piñon well (sec. 8 T2S R6W unsurveyed) in the Gallinas Peak quadrangle (Osburn and Laroche, 1982; Osburn and Chapin, 1983a), is petrographically a rhyodacitic to rhyolitic lava flow or series of flows. In the southeast corner of the Lion Mountain quadrangle, near Deep well, the rhyolite of Piñon Well might overlie the Vicks Peak Tuff, although this relationship is not clearly exposed. No La Jara Peak lavas or conglomeratic sedimentary rocks are found here, and the rhyolite of Piñon Well is overlain by the South Canyon Tuff.

Locally, in the southern part of the map area, poorly to moderately welded, phenocryst-poor ash-flow tuffs (*Tpwt*) underlie the rhyolite of Piñon Well and are interpreted as early pyroclastic equivalents of the lavas. Extensive outcrops of petrographically similar rhyolite lavas can be found in this stratigraphic interval about 10 mi (16 km) to the south in the northwestern San Mateo Mountains (G. R. Osburn, unpubl. map 1984). Here the lavas are called the rhyolite of Durfee Canyon, and they crop out between Vicks Peak Tuff and the overlying Lemitar Tuff.

The rhyolite of Piñon Well is glassy to lithoidal and sparsely porphyritic, containing 1–3% sanidine phenocrysts. Spherulitic devitrification textures, including globular spherulites several centimeters across, are common. A vent area for these rhyolites is not clearly exposed; however, several areas of steep foliation and brecciation in exposures along the eastern edge of the Lion Mountain quadrangle and the western edge of the adjoining Gallinas Peak quadrangle are suspected to be vents.

La Jara Peak Basaltic Andesite and unnamed sedimentary rocks

Mafic lavas of the La Jara Peak Basaltic Andesite (*Tlp*) interfinger with the ash-flow tuff sequence throughout the region. These lavas are first seen overlying the La Jencia Tuff and persist well above the South Canyon Tuff. Within this map area, the oldest mafic lavas separate the Vicks Peak and South Canyon Tuffs. These lavas, exposed in the east-central part of the map area, are typically thin, dark-gray, slightly porphyritic, vesicular basalt or basaltic-andesite flows intercalated with sandstones and conglomerates. The rocks contain a small percentage of clinopyroxene and olivine phenocrysts, and some have plagioclase phenocrysts. Phenocryst phases and plagioclase compositions (An74) suggest that these rocks are basalts (Laroche, 1980); however, chemical analyses have not been done.

The unnamed sedimentary rocks interbedded with these mafic lavas (*Tvs2*) consist of interlayered volcaniclastic sandstones and conglomerates. The sandstones are moderately to poorly sorted and fine to coarse grained and consist of varying proportions of mineral and lithic grains. The conglomeratic intervals contain pebble- to cobble-size clasts in a similar sandy matrix. Clasts are mainly purple to black mafic rocks, gray silicic lavas (possibly the rhyolite of Piñon Well), and red silicified sandstone fragments (possibly the Abo Formation). The sandstones and volcanic clasts suggest fairly local sources within the volcanic region. The Abo-like clasts, however, imply either longer transport or a local exposure now buried.

These sedimentary rocks, as with the previously described interval between the La Jencia and Vicks Peak Tuffs, may be deposited in a wedge-shaped depression along a slightly rotated normal fault and may document the onset of extension in this area; however, exposures are too scattered to evaluate the geometry of this deposit. A few miles to the east, mafic lavas dominate the interval between Vicks Peak and South Canyon Tuffs. To the south, however, the next exposure of this stratigraphic interval contains only the rhyolite of Piñon Well.

South Canyon Tuff

The South Canyon Tuff (*Tsc*) is the youngest major regional ash-flow tuff exposed in the northeastern Mogollon–Datil volcanic field. Within the study area, the South Canyon Tuff overlies the rhyolite of Piñon Well and the La Jara Peak Basaltic Andesite. The South Canyon Tuff varies in thickness from 650 ft (200 m) or more on Lion Mountain to less than 300 ft (90 m) at Antelope Flats where it overlies the rhyolite of Piñon Well. This thinning suggests that the rhyolite of Piñon Well formed topographic highs at the time of the South Canyon eruptions. The South Canyon Tuff is not exposed north of Lion Mountain and Antelope Flats. This termination of exposures suggests that the area to the north was topographically high during South Canyon emplacement. A highland to the north at this time agrees with the uplift and erosion documented at the base of the Vicks Peak Tuff. The South Canyon Tuff was erupted from the San Mateo Mountains about 20 mi (32 km) south of this map area, where the unit is as much as 3,000 ft (900 m) thick (Ferguson, 1986, 1991; Osburn and Ferguson, 1986).

The South Canyon Tuff within this map area consists of a simple cooling unit and was mapped undivided. However, two lithologic members can be recognized by total phenocryst content and texture. The thick, lower, crystal-poor member is overlain by, and welded to, a thinner, moderately crystal-rich member. Both members contain subequal amounts of quartz and sanidine phenocrysts, with traces of biotite and sphene, and have quartz–sanidine ratios of approximately one. The lower member is light-gray to brownish-gray, densely welded rhyolite tuff and forms a colluvium of small plates during weathering. It contains approximately 5% phenocrysts. A black vitrophyre is commonly present a few meters above the base. The upper member is medium-gray to purplish-gray, moderately welded rhyolite tuff; typically it stands as low cliffs and contains approximately 15% total phenocrysts. The lower member is several hundred feet thick in the Lion Mountain area; the upper member is about 100 ft (30 m) thick.

A thin interval of volcaniclastic sandstone and conglomerate (*Tvs3*) overlies the South Canyon Tuff in discontinuous, poorly exposed outcrops. Clasts are mostly rhyolite of Piñon Well or South Canyon Tuff. Otherwise the sediments closely resemble the two older intervals of sedimentary rocks (*Tvs1* and *Tvs2*).

Andesite of Lion Mountain

A thick sequence of porphyritic andesitic lavas overlies the South Canyon Tuff as the uppermost volcanic unit in the Lion Mountain area. These lavas were informally named the andesite of Lion Mountain (*Tlm*) after the thick exposures that cap these hills (Osburn and Laroche, 1982; Osburn and Chapin, 1983a). The andesitic lavas can be found from Lion Mountain eastward for about 6 mi (10 km) to near the center of the Gallinas Peak quadrangle and southward at least to US–60. The quarry from which crushed rock was obtained for construction of the VLA (Very Large Array radio telescope) is in these andesites (sec. 36 T2S R7W).

The andesites of Lion Mountain are dark gray to purple and typically contain from 10% to 25% total phenocrysts consisting predominantly of plagioclase, with minor pyroxene and magnetite; some flows contain biotite, and others contain olivine. The plagioclase phenocrysts are large (>5 mm) and are often partially to well aligned parallel to flow directions. These large tabular phenocrysts give the rocks a distinctive texture (Fig. 3). Similar rocks in other areas have been termed "turkey-track andesites," where alignment of plagioclase phenocrysts is weak, or "platy-plagioclase andesites," where the phenocrysts are strongly aligned. These andesites are as much as 600 ft (180 m) thick on Lion Mountain, and several flows can be identified locally. Exposures are not sufficient, however, for mapping of individual flows throughout the area. In general, the flow bases are relatively phenocryst poor, dense, and platy, whereas the tops are highly porphyritic and typically quite vesicular and rubbly.

One possible vent area for the andesite of Lion Mountain is in the east-central part of the map area; it is defined by steep foliation and a surrounding zone of red hematite staining. Two small porphyritic dikes (*Tad*) with texture and mineralogy similar to that of the andesite of Lion Mountain intrude the lower La Jencia Tuff in the north-central part of the quadrangle; they suggest a second possible vent area. Several more dikes are found just off the southeastern corner of this map area in the Gallinas Peak and Tres Montosas quadrangles. A vent area for the eastern part of these lavas was reported in the central Gallinas Peak quadrangle (7914

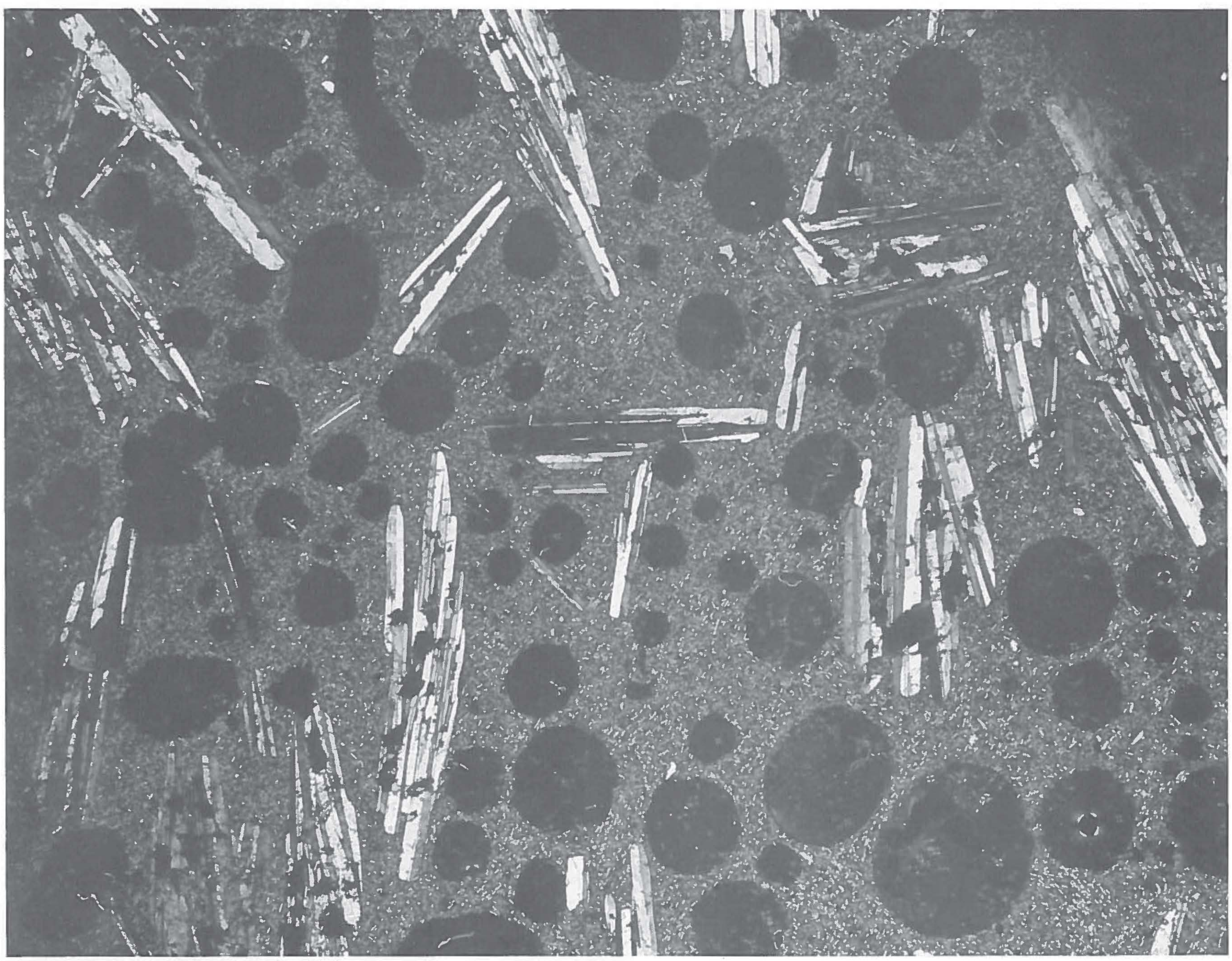
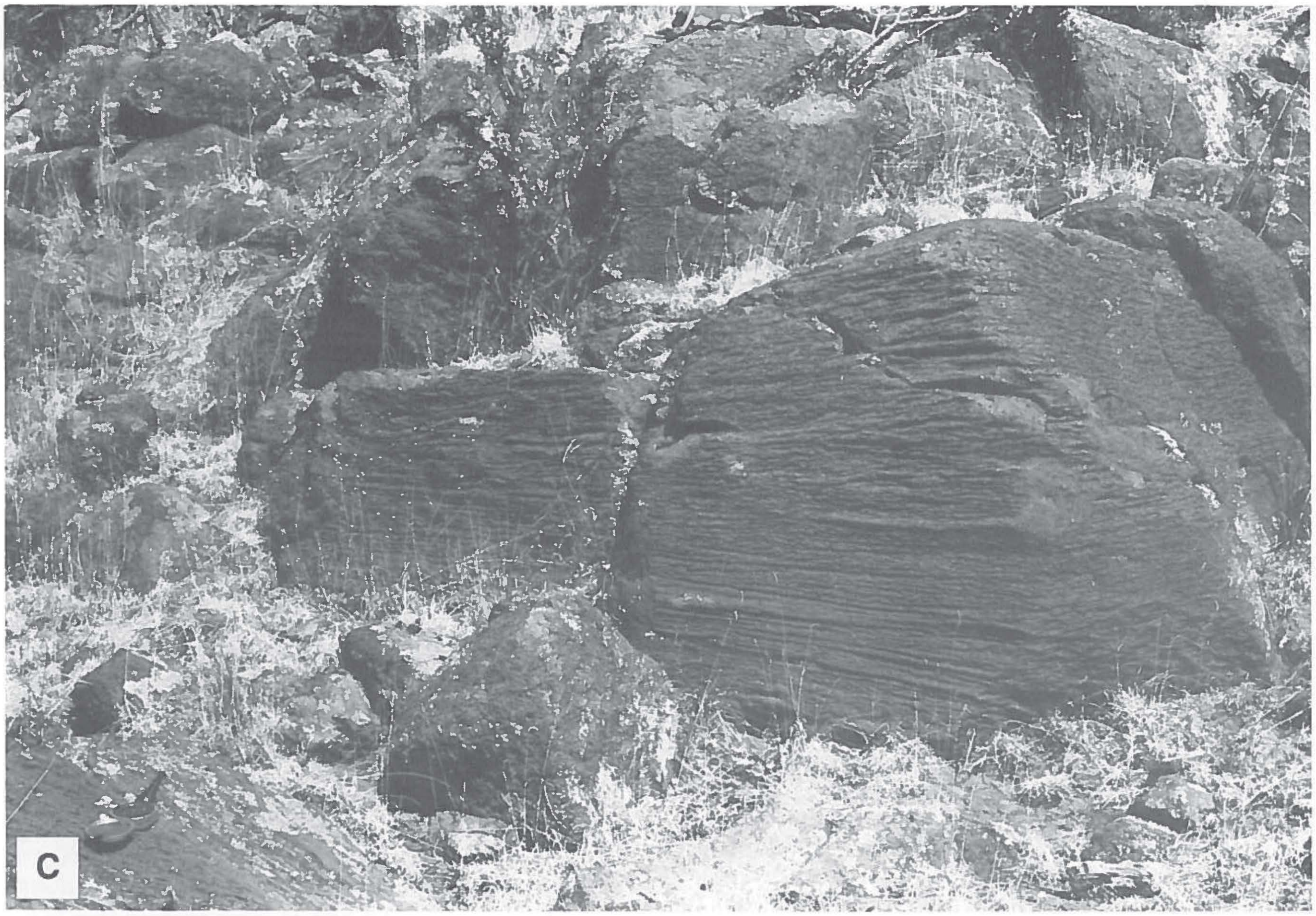


FIGURE 3—Photomicrograph of the andesite of Lion Mountain showing the typical large plagioclase phenocrysts within a fine-grained groundmass of plagioclase microlites and ferromagnesian minerals. Field of view is approximately 2 cm.

FIGURE 4—Series of photographs showing the wind-scoured rocks found on the tops of the higher hills of Lion Mountain. Photograph A is taken looking west along the strike of the grooving toward the Plains of San Agustin. The plains are a closed basin that contained an extensive lake (or lakes) during pluvial episodes of the Pleistocene. The lake beds provided abundant sand during drier times (of the Holocene). Round white spot is a VLA radio antenna. Photograph B shows the grooved face of a southwest-facing cliff located just down the west side of the hill from photograph A. The pencil-shaped eraser is about 6 inches (15 cm) long and points north (left). Photograph C shows a spectacularly grooved rock face on a south-facing slope near the site of photograph A (compass points to the north). Photograph D shows scour grooves crossing the flow foliation of the andesites at a high angle. The flow foliation is defined by elongate and flattened vesicles, which are common in the andesite of Lion Mountain. Azimuths taken on the long dimensions of these vesicles give last-movement transport directions; however, these data are seemingly too erratic to help locate vents.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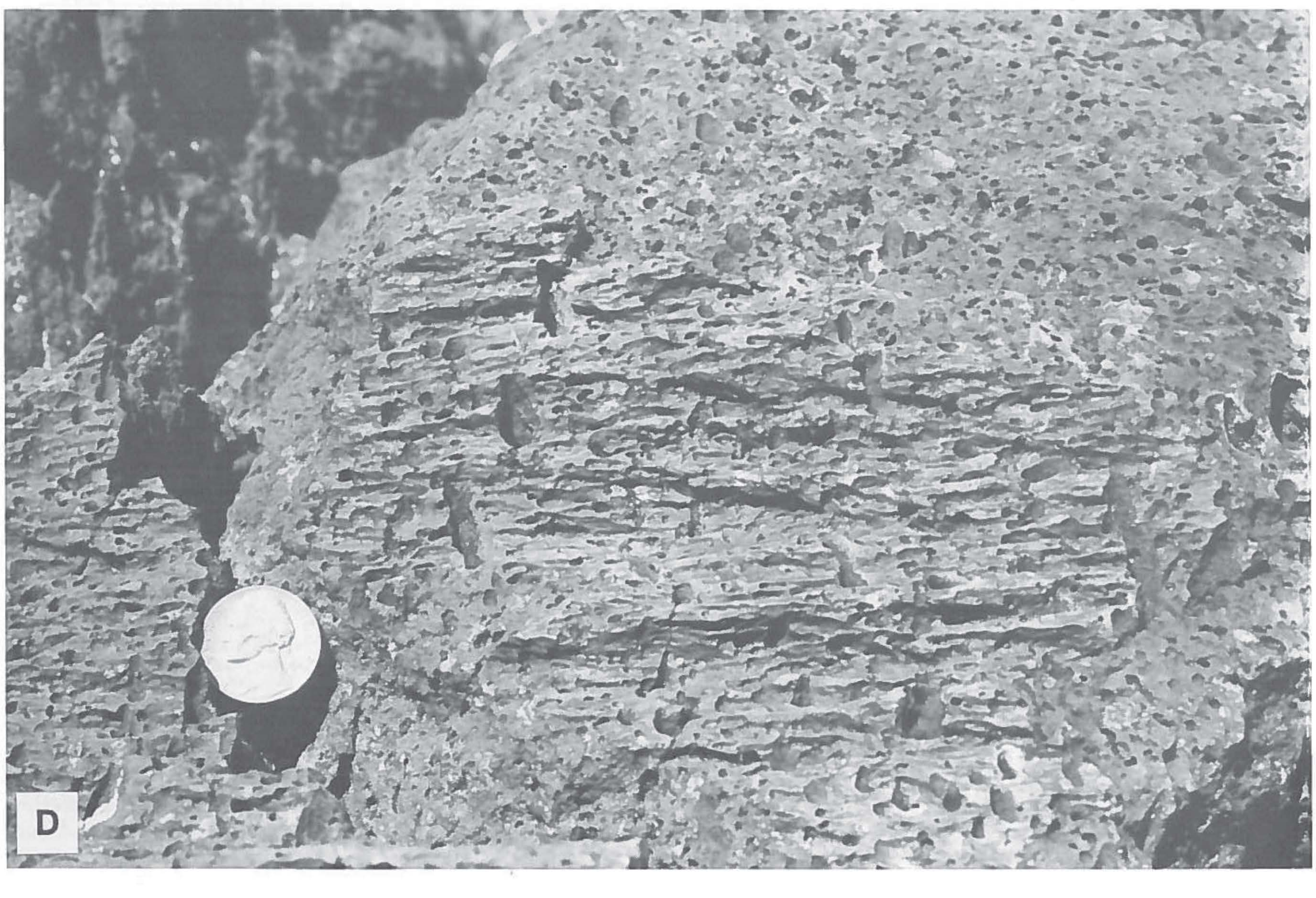
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hill) by Chamberlin (1974)—his "andesite of Landavaso Reservoir." Lineation directions taken on flattened and elongated vesicles indicate last-movement transport for many areas; however, these lineation directions did not define any vent areas. These strongly porphyritic lavas were probably rather viscous, and several vents are possible for an outcrop area of this size. Other undiscovered vents may exist in addition to the ones described above.

East of the map area the andesite of Lion Mountain was miscorrelated by Chamberlin (1974) with the andesite of Landavaso Reservoir (Simon, 1973). Similarly, isolated outcrops a few miles south of US–60 and west of Gray Hill, mapped by Wilkinson (1976) as andesite of Landavaso Reservoir, are the andesite of Lion Mountain. These two andesite units, although petrographically quite similar, are now known to be separated stratigraphically by two regional ash-flow tuffs and by a time interval of at least 3 m.y. (Osburn and Chapin, 1983a).

Quaternary surficial deposits

Quaternary, and perhaps latest Tertiary, surficial deposits cover approximately 60% of the Lion Mountain map area. These deposits, in general, comprise the basin floor of Pleistocene Lake San Agustin and piedmont-slope deposits graded to the basin. The lake basin and surrounding piedmont apron are largely undissected; therefore, exposures are limited to the uppermost parts of these deposits. In addition, eolian sand now buries these deposits throughout most of the map area. Arroyos on the piedmont slopes are entrenched as much as 10 ft (3 m) but commonly expose only well-sorted sand. A detailed study of these poorly exposed but extensive deposits was beyond the scope of this report. The Quaternary units, therefore, were divided into piedmont-slope (*Qp*), lacustrine (*Ql*), colluvial (*Qtc*), basin-floor (*Qa*), and eolian-sand (*Qs*) deposits. Contacts were often difficult to pick, even for these simplistic units. Aerial photographs and U.S. Soil Conservation Service soil maps were used to supplement field observations in difficult areas. Most users of this map should consider the contacts between Quaternary units reconnaissance in nature.

On the windward side of hills interesting surface features have been eroded into the older volcanic rocks by sand blown from the Plains of San Agustin (Fig. 4). Most of these windward rocks are pitted and, on the top of Lion Mountain, grooved parallel to the dominant effective wind direction. In several areas on Lion Mountain, these grooved outcrops gave a fairly consistent wind direction of approximately N60–65°E. Falling dunes on the east and northeast sides of the larger hills confirm this general direction of transport, as does the orientation of parabolic dunes and elliptical blowouts on the southwest sides.

STRUCTURE

The Lion Mountain map area is fairly simple structurally compared with much of the Socorro–Magdalena area. Within this area rocks vary in attitude from flat lying to moderately dipping (dips as great as 15°). Only a few faults, showing normal separation, are mapped. Two fault trends, N45–60°W and N20–45°E, dominate, and most faults are downthrown to the west toward the San Agustin Basin. Regardless of trend, the faults are thought to be contemporaneous because, in several areas, most of the stratigraphic separation on a fault of one trend can be seen to shift to a fault of the other trend.

The rocks within this quadrangle are gently folded in addition to being faulted. These folds consist of broad, open synclines and one possible anticline. The fold axes generally parallel one of the two fault trends (Fig. 5) and are thought to have formed more or less contemporaneously with the faults. This parallelism suggests that the folds might have formed by draping over faults (horsts and grabens) concealed at depth. Pennsylvanian, Permian, Triassic, and Cretaceous mudstone and shale intervals are present beneath this map area unless eroded in Laramide time. Any of these might have stretched rather than fractured above upward-propagating faults. A sag, once begun, would have propagated upward through stronger and more brittle rocks.

The age of the folding and faulting within the Gallinas and Datil Mountains is not well established. Harrison (1980) demonstrated that at least part of the folding and uplift in the eastern Datil Mountains occurred after emplacement of La Jencia Tuff and before Vicks Peak Tuff (28.56 ± 0.04 Ma; McIntosh et al., 1990). In the Lion Mountain quadrangle, local areas of volcaniclastic sedimentary rocks are interbedded between La Jencia and Vicks Peak Tuffs, between Vicks Peak and South Canyon Tuffs, and between South Canyon Tuff and the andesite of Lion Mountain. These sedimentary rocks may represent deposition in strike valleys on the down side of normal faults. If this interpretation is correct, episodic faulting occurred from La Jencia deposition onward. Other faults and folds in Harrison's (1980) area and in the Lion Mountain quadrangle are younger than the South Canyon Tuff (27.36 ± 0.07 Ma; McIntosh et al., 1990) and the andesite of Lion Mountain (undated). No younger age constraint is available for these younger faults except that they do not cut surficial deposits. One young, probably Quaternary, fault cuts basin-fill sedimentary deposits a few miles northwest of the Lion Mountain quadrangle.

As originally mapped by Weber, the VLA fault of McFadden (Menges et al., 1984) extends in a northerly to north–northwesterly direction across the southwestern edge of the Arrowhead Well quadrangle, south of the area of this map. Although the fault has offset piedmont-slope deposits of the San Mateo Mountains, no evidence was found of its continuation through the Pleistocene lake deposits (*Ql*) southwest of the VLA headquarters. The persistently horizontal attitude of shorelines at constant levels indicates no significant post-lake deformation throughout the basin.

Several very minor faults were noted in the wave-guide trench along the north arm of the VLA, but these are presumed to be products of desiccation of the lake beds rather than tectonic events. A more significant product of this process is the series of giant polygonal fissures that disrupt the lake beds in the central part of the basin (Neal, 1965; Neal and Motts, 1975). Surface drainage intercepted by these fissures leads to the development of conical pits by piping action. The expansive nature of thick beds of lacustrine clays probably contributes to the process, which continues to be active today.

ECONOMIC GEOLOGY

A few areas of alteration, locally mineralized, were mapped in the Tres Montosas and Gallinas Peak quadrangles to the east of this area (Chamberlin, 1974; Wilkinson, 1976; Laroche, 1980) and in the Indian Mesa and Dog Springs quadrangles to the northwest (Givens, 1957; Harrison, 1980; Coffin, 1981). Little alteration or other evidence for mineralization was seen within the Lion Mountain map area during this study. One small area of hematite staining was found in the first andesite hills south of Antelope Flats in the east-central part of the map area. Although a number of shallow prospect pits were dug in these hills no evidence of mineralization except reddened rock and minor calcite veining

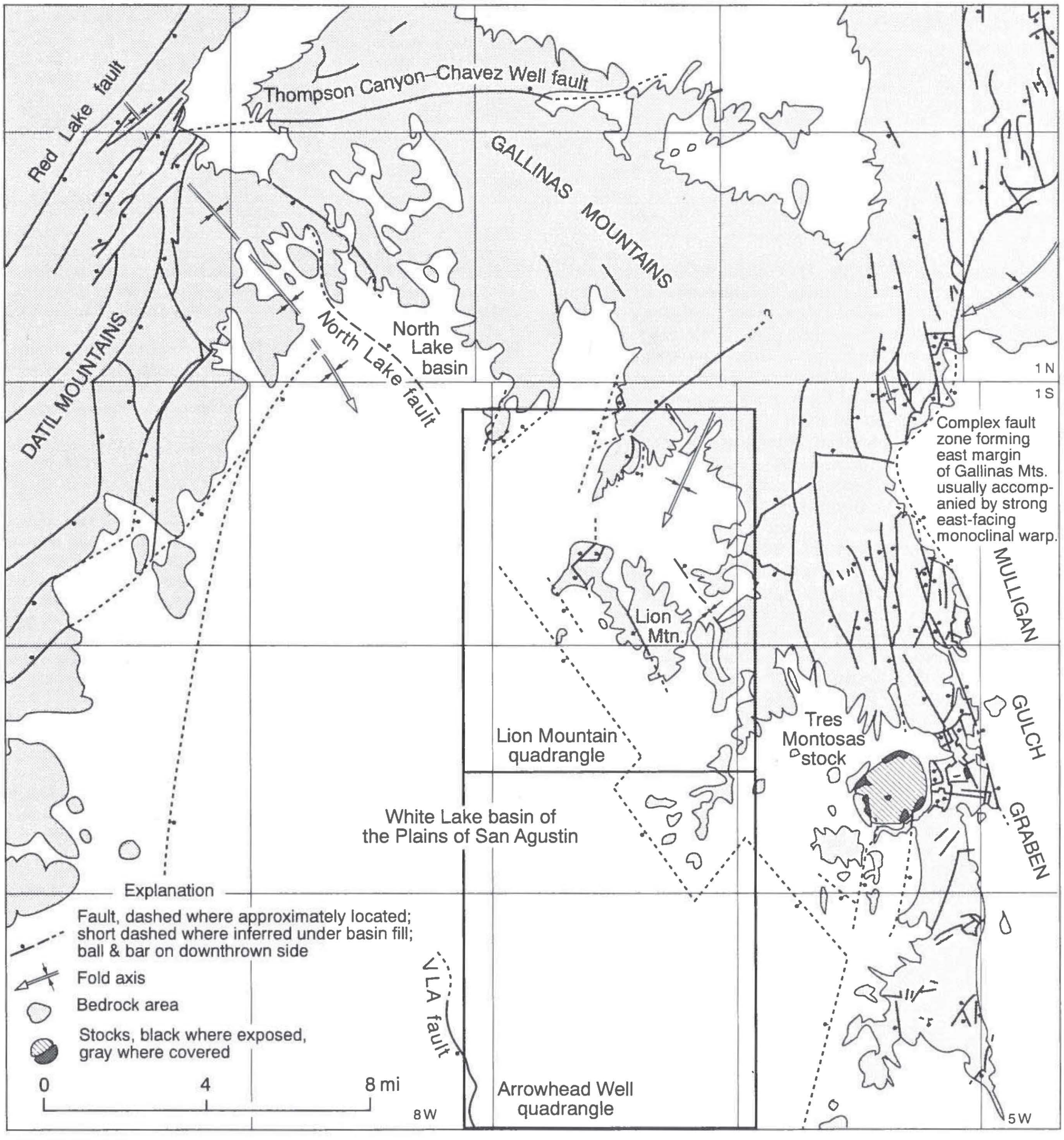

FIGURE 5—Map of the bedrock areas, plutons, faults, and fold axes surrounding the Lion Mountain map area. All of the bedrock areas are Tertiary volcanic and sedimentary rocks except for small areas in the northeastern and northwestern parts. Clearly shown in the fault patterns are the complex fault zones along the eastern side of the Gallinas Mountains and along the Red Lake fault; the block between is much simpler structurally. All folds on this map affect mid-Tertiary rocks and thus cannot be Laramide in age. Other folds entirely within Cretaceous rocks just off the northern edge of this compilation may be either Laramide or mid-Tertiary in age.

TABLE 1—Approximate thicknesses for the stratigraphic sequence beneath exposed volcanic units. Data for immediate area are not available. References listed are to areas north and south of the Lion Mountain quadrangle where older stratigraphic sequences are exposed. Some of these units may be absent or thin in the Lion Mountain area because, in general, the region to the south was high and subject to erosion during Laramide time.

Stratigraphic unit	Thickness (ft)	Reference	Location of study
Hells Mesa Tuff (Oligocene)	500–800	this report	
Datil Group (Oligocene)	1,500–2,000	Wilkinson, 1976	Tres Montosas/Cat Mountain
Baca Formation (Eocene)	900	Cather, 1980	northern Gallinas Mountains
Cretaceous rocks	2,200	Osburn, J. C., 1984	Pueblo Viejo Mesa 7½-min quadrangle
Triassic rocks	1,200–1,800	Osburn, J. C., 1984	Pueblo Viejo Mesa 7½-min quadrangle
		Jicha, 1958	Mesa del Oro
Permian rocks	3,000	Jicha, 1958	Mesa del Oro
Pennsylvanian rocks	1,000	Kottlowski, 1960	southwestern New Mexico

was observed in these pits. This oxidation is thought to be related to a small vent for part of the andesite of Lion Mountain. Small areas of silicification were seen along a few of the faults in the north-central part of the map area, but none of these were large or contained any obvious mineralization. Upper Cenozoic lake-basin sediments in the west half of the map area and farther west were considered to be possible hosts for uranium deposits, but exploratory drilling was unsuccessful in locating mineralization of potentially commercial significance.

Because the Lion Mountain map area is situated on an outflow area peripheral to the main part of the Mogollon–Datil volcanic field and is not known to contain cauldrons or major intrusions, a potential for discovery of oil and gas may exist in Mesozoic or Paleozoic rocks beneath the volcanic cover. Table 1 lists approximate thicknesses for stratigraphic units in nearby areas where they are exposed. Estimates of depth to pre-Cenozoic rocks within this area range from 3,000 to 15,000 ft (900–4,500 m). Part of the pre-Cenozoic section, however, may have been eroded during Laramide tectonism. The late Laramide (Eocene) Baca Basin lay to the north of this area, and contemporary highlands are postulated to the south (Cather, 1980; Cather and Johnson, 1984). Farther east these highlands are exposed in the Magdalena Mountains where early Tertiary erosion has generally removed all rocks above the Pennsylvanian. Within this quadrangle no pre-Cenozoic rocks are exposed, and subsurface data are sparse for the surrounding area. Chapin et al. (1979) discuss the oil and gas potential of the Riley–Puertecito area to the northeast of the Lion Mountain quadrangle.

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