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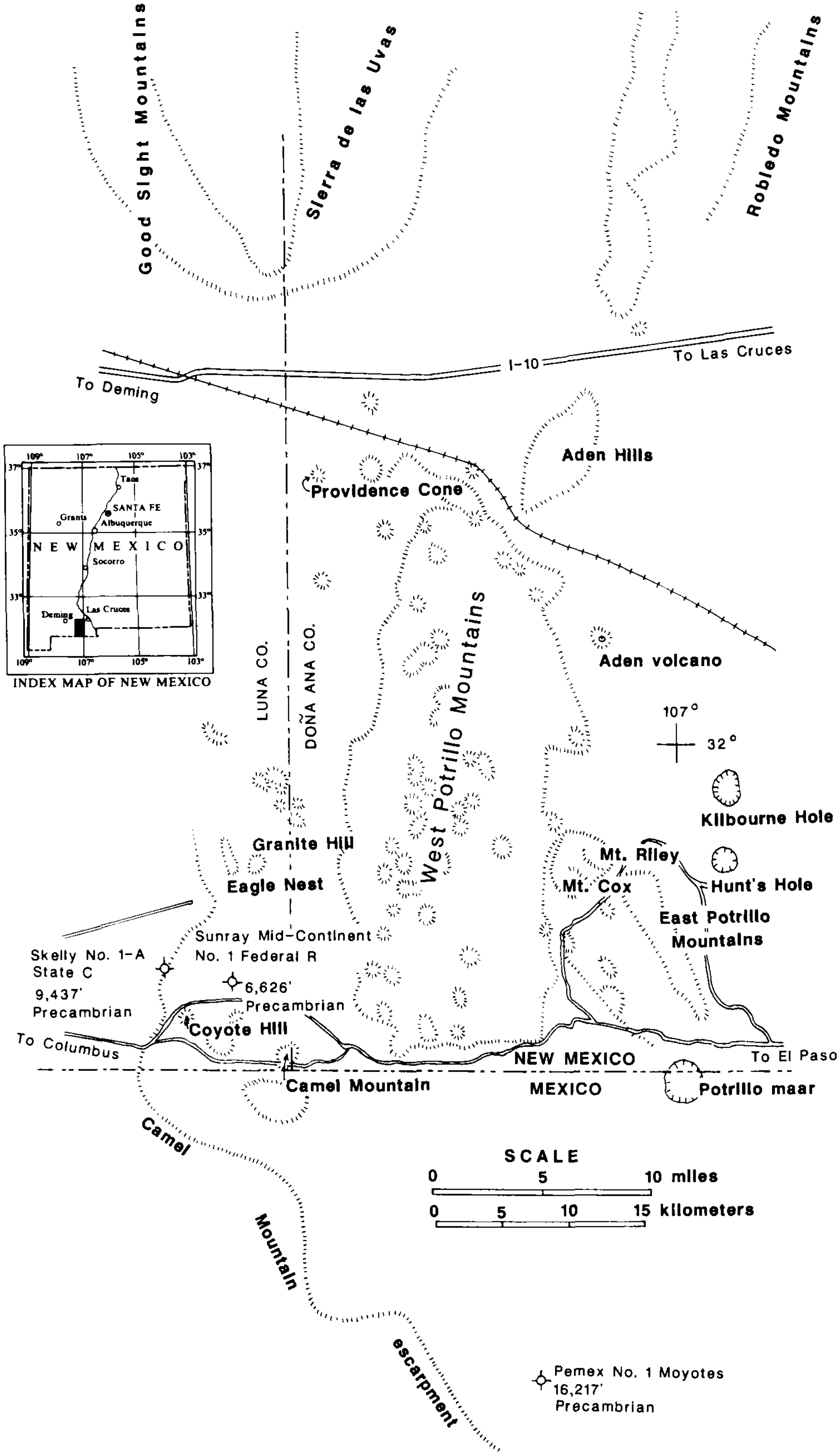

FIGURE 1—Location map of the West Potrillo Mountains and vicinity.

Introduction

The West Potrillo Mountains, located 30 mi southwest of Las Cruces, New Mexico (Fig. 1), are known as one of the largest concentrations of basaltic volcanoes in the United States. Lying near the southern end of the Rio Grande rift, the volcanoes are part of an assemblage of young volcanic fields that dot the rift throughout its length. More than 100 cinder cones, small shield volcanoes, and maars are so nearly untouched by erosion that their youthful age is obvious. Radiometric dates from 1.2 Ma to 0.1 Ma have been determined, but some volcanoes may be as old as late Pliocene or as young as 20,000 years (Seager et al., 1984; Gile, 1987). Lava flows associated with the volcanoes cover more than 200 mi². Known as the West Potrillo Basalt (Hoffer, 1976), these lavas have mostly buried an array of older rocks and structures whose ages and geometries have been discussed only briefly in previous publications. The purpose of this paper is to summarize current interpretations of these rocks and structures.

The pre-Quaternary geology of the West Potrillo Mountains is revealed in three ways: 1) by scattered outcrops of older rocks around the perimeter of the basalt, 2) by gravity data (Lance and Keller, 1981; DeAngelo and Keller, 1988), and 3) by two important oil tests, the Sunray Mid-Continent No. 1 Federal R and the Skelly No. 1-A State C wells (Fig. 1). These data permit reconstruction of a stratigraphic column for the area (Fig. 2) and an interpretation of the main tectonic features (Figs. 3 and 4). Much of the outcrop data is new, the result of mapping for the SW1/4 of Las Cruces and NW El Paso 1° x 2° sheet (Seager, in press). Important previous work on pre-Quaternary rocks of the area includes Hoffer, 1976; Kottlowski et al., 1969; Hoffer and Sheffield, 1981; Hoffer and Hoffer, 1981; Broderick, 1984; Lance and Keller, 1981; Thompson, 1982; and Kilburn et al., 1988.

Stratigraphy

Assembling a stratigraphic column of pre-Quaternary rocks in the West Potrillo Mountains area is an uncertain task because outcrops are small and separated by wide tracts of sand and/or basalt. Stratigraphic relationships from one outcrop to the next are seldom clear, especially in the Tertiary section. Nevertheless, a general stratigraphic order (Fig. 2) is apparent, based mostly on outcrops from the western and northern margin of the basalt field and the East Potrillo Mountains, as well as on data from the two drill holes.

Precambrian and Paleozoic rocks

Precambrian gabbro and granite were drilled in the Sunray and Skelly wells, respectively, beneath lower Paleozoic sedimentary rocks (Thompson, 1982; Kottlowski et al., 1969). Bliss Sandstone, El Paso Formation, Simpson(?) Formation, Montoya Formation, and Fusselman Dolomite were recognized in the Sunray well. Thicknesses of several of these units shown in Figure 2 are not corrected for Tertiary igneous intrusions or possible steep dips. In the Skelly well, Bliss and lower El Paso are missing by faulting and Simpson(?) and Fusselman are missing by erosion. Middle and upper Paleozoic strata are absent from both wells because of erosion (Thompson, 1982).

Permian carbonate rocks crop out in widely scattered hills from Eagle Nest (Fig. 1) southward to the Mexico border and eastward to the East Potrillo Mountains. Incomplete sections of Hueco (Colina), Yeso (Epitaph), and San Andres Formations have been tentatively identified on the basis of fossil content and lithologic similarity with Permian rocks exposed in the Franklin, Robledo, and Caballo Mountains and in the West Lime Hills of the Tres Hermanas Mountains. Apparently these Permian strata are widespread across the southern part of the West Potrillo Mountains area in contrast to Devonian, Mississippian, and Pennsylvanian rocks, which were eroded during mid-Wolfcampian time (Thompson, 1982).

One mile east of Eagle Nest the entire Paleozoic section is missing, and Upper Cretaceous or lower Tertiary clastic strata overlie Precambrian granite. Laramide, as well as possible Early Cretaceous and mid-Wolfcampian uplift and erosion may account for the absence of Paleozoic strata there.

Mesozoic rocks

Lower Cretaceous rocks—These rocks crop out in the East Potrillo Mountains as well as at Eagle Nest. In the former area Seager and Mack (in press) measured 1,900 ft of marine clastic and carbonate shelf deposits above a basal conglomerate, all of which thin southward. These somewhat-arkosic clastic rocks and limestones contain an Albian–Aptian fauna and correlate with the Hell-to-Finish and U-Bar Formations of southwestern New Mexico. At Eagle Nest, approximately 1,000 ft of marine and nonmarine Hell-to-Finish and U-Bar strata are upside down beneath Permian carbonates and a Laramide thrust fault. Two coarse-grained arkose tongues in the Hell-to-Finish Formation suggest a nearby granitic source, and one mile to the east a fault block of Precambrian granite was possibly exposed during Early Cretaceous time.

Upper Cretaceous to lower Tertiary rocks—One mile east of Eagle Nest the fault block named Granite Hill by Broderick (1984) also exposes a series of arkosic siltstone, sandstone, conglomerate, and minor limestone beds that nonconformably overlie the Precambrian granite. Conglomerate beds

Chronostratigraphic Units	Symbols for Figure 4		Thickness (ft)	Lithostratigraphic Units
Late Pliocene - Pleistocene	Q Qb (basalt) QTa		300	Fanglomerate, eolian deposits; basalt
Miocene			0-2,000	SANTA FE GROUP, lower part; conglomerate and sandstone
Oligocene	Tv		500 ±	UVAS BASALTIC ANDESITE
			1,500 (?)	BELL TOP FORMATION; latite and latite porphyry flows at top; flow-banded rhyolite; felsite; rhyolite ash-flow tuff; andesite flows and domes; silicic to intermediate composition intrusives
Late Eocene - early Oligocene			1,500 (?)	RUBIO PEAK FORMATION; intermediate-composition flows and volcaniclastic rocks
Eocene	Tl		1,000	LOVE RANCH FORMATION; sandstone and conglomerate / LOBO FORMATION; arkose, conglomerate, siltstone, limestone
Late Cretaceous - early Tertiary			780	?
Early Cretaceous	Kl		500	U-BAR FORMATION; limestone
			440	HELL-TO-FINISH FORMATION; conglomerate, arkose, sandstone, limestone
Permian	Pal	P	400	SAN ANDRES FORMATION; limestone
			800	YESO (EPITAPH) FORMATION; dolomitic limestone
			1,000 (?)	HUECO (COLINA) FORMATION; limestone, shale
Silurian			650	FUSSELMAN DOLOMITE
Ordovician			818	MONTOYA DOLOMITE
			376	SIMPSON FORMATION (?); Shale or sandstone
			1,595	EL PASO FORMATION; limestone, dolomite with intrusives
Cambrian and Ordovician			175	BLISS FORMATION; sandstone and shale
Precambrian	p€			Granite

Precambrian granite at Granite Hill

FIGURE 2—Composite stratigraphic column for the West Potrillo Mountains area.

contain clasts of Lower Cretaceous carbonates (Broderick, 1984) and are therefore younger than Early Cretaceous. Regional relationships and physical characteristics suggest correlation of these conglomerates and arkosic strata with the Lobo Formation, which is probably of either Late Cretaceous or early Tertiary age (Clemons, in press; Seager and Mack (1986). The arkosic rocks seemingly indicate uplift and erosion of the underlying and adjacent Precambrian granite during Laramide time, but the Lower Cretaceous arkose in the Hell-to-Finish Formation of the nearby Eagle Nest outcrops also suggests uplift and erosion of the granite or some other nearby granite mass in Early Cretaceous time.

Tertiary rocks

A wide variety of rocks of probable Tertiary age crop out around the perimeter of the West Potrillo Basalt field. They can be divided into six groups: 1) Love Ranch Formation, essentially nonvolcanic clastic rocks, 2) Rubio Peak Formation, intermediate-composition volcanic rocks, 3) Bell Top Formation and related silicic volcanic rocks, 4) medium- to coarse-grained intrusive rocks of intermediate composition, 5) Uvas Basaltic Andesite, basaltic andesite flows, 6) Santa Fe Group, fanglomerate derived largely from volcanic rocks.

Love Ranch Formation—The oldest Tertiary unit consists of conglomerate, sandstone, and shale that crop out along the flanks of the Mt. Riley–Mt. Cox plugs on the southeastern flank of the West Potrillo Mountains (Fig. 1). Lowest exposures are cobble–boulder conglomerates consisting of Lower Cretaceous and Permian detritus similar to the outcropping Permian and Cretaceous rocks of the East Potrillo Mountains. Red mudstone and siltstone are interbedded, and there are no volcanic clasts. The sequence resembles the Eocene Love Ranch Formation of the Caballo–San Andres Mountains area with which it was correlated by Seager and Mack (in press). Higher parts of the section include tan to olive sandstone and shale as well as conglomerate, all of which have a significant component of andesite and rhyolite clasts.

Rubio Peak Formation—Andesitic flows and breccia overlie the Love Ranch Formation on the flanks of the Mt. Riley–Mt. Cox plugs, and the same rocks form the Aden Hills (Fig. 1) at the northeastern corner of the West Potrillo basalt field. These andesitic rocks seemingly are correlative with the Rubio Peak and Palm Park Formation of late Eocene age in the Sierra de las Uvas–Good Sight Mountains–Florida Mountains area (Clemons, 1977; 1979; in press).

Bell Top Formation and related rocks—Masses of flow-banded rhyolite, lithic and vitric ash-flow tuff, and latite and latite porphyry flows crop out in small, widely separated hills on the Camel Mountain fault block (Figs. 1, 3). Similar volcanics also were penetrated in the Sunray Mid-Continent No. 1 and Skelly 1–A wells, described by Hoffer (1986). In outcrops, the latite and latite porphyry flows underly Uvas Basaltic Andesite in the hills 4 mi north of Eagle Nest; elsewhere, stratigraphic relationship of the silicic volcanics is unclear. They are probably correlative with the Bell Top Formation of Oligocene age of the Sierra de las Uvas area (Seager, 1973). The Bell Top also consists predominantly of silicic ash-flow tuffs and flow-banded rhyolite beneath basaltic andesite flows (Uvas Basaltic Andesite). Distal parts of Bell Top tuffs 4 and 6, as well as Bell Top sedimentary rocks, crop out beneath Uvas Basaltic Andesite flows along the northern margin of the West Potrillo basalt field.

Finally, the large andesitic plug or plugs of Mt. Riley and Mt. Cox probably are also correlative with the Bell Top Formation. Although undated, these plugs are probably Oligocene in age because they intrude Love Ranch and Rubio Peak Formations and furnished clasts to Miocene fanglomerate.

Plutonic or hypabyssal intrusives—Intrusive rocks are coarse-grained equigranular or porphyritic masses that crop out at Providence cone, in the hills west of Camel Mountain, and at Granite Hill (Fig. 1). The intrusive at Providence cone is biotite latite porphyry whereas the intrusives in the other two areas are equigranular diorite and hornblende monzonite porphyry. At Granite Hill, dike-like intrusives have invaded Upper Creta-

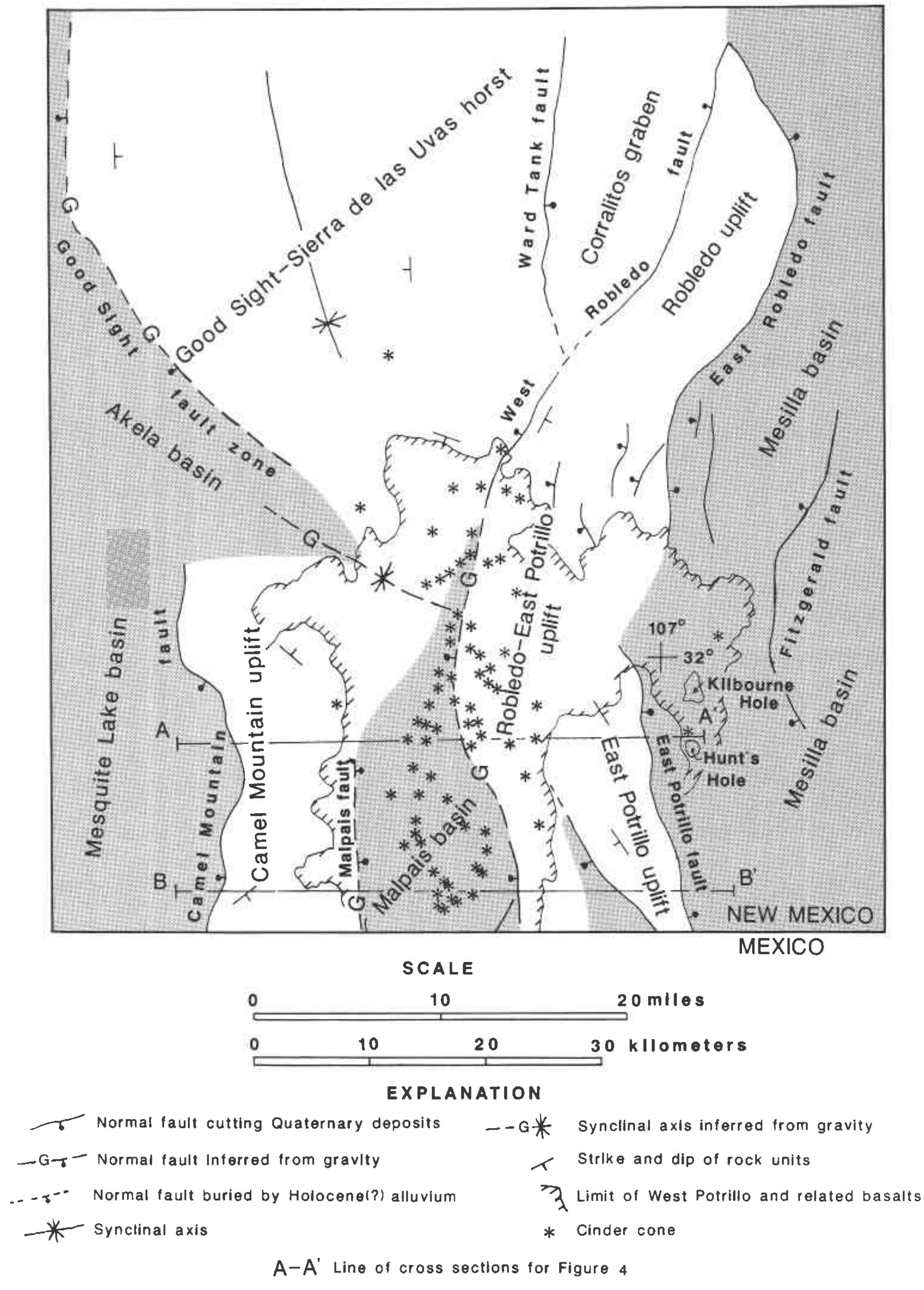

FIGURE 3—Tectonic map of West Potrillo Mountains area. Shaded areas are basins with known or inferred thick basin fill.

ceous or lower Tertiary strata, and in the hills west of Camel Mountain unidentified metamorphosed limestone has been cut by the intrusion. Undated, the intrusives may be Laramide or, more likely, middle Tertiary in age. Because outcrops in each area are confined to isolated hills, the extent of the plutons is also unknown.

Uvas Basaltic Andesite—Basaltic andesite flows in the West Potrillo Mountains area are probably correlative with the Uvas Basaltic Andesite of the Sierra de las Uvas area. The flows crop out along the northern edge of the West Potrillo basalt field and in the hills 4 mi northeast of Eagle Nest. In these respective areas the flows overlie Bell Top tuffs or sediment and latite porphyry flows. Islands of basaltic andesite flows also are scattered within the northern part of the West Potrillo basalt field. With an age of 27–28 Ma in the Sierra de las Uvas region (Clemons, 1979), the basaltic andesites are the youngest radiometrically dated pre-Quaternary volcanic rocks in the West Potrillo Mountain area. However, undated masses of rhyolite, which crop out near the axis of the Akela basin syncline, appear to overlie the basaltic andesite and may be younger.

Santa Fe Group (lower)—Fanglomeratic strata consisting of conglomerate, conglomeratic sandstone, and sandstone compose the lower part of the Santa Fe Group. These are tilted alluvial fan deposits exposed at Camel Mountain and along the western edge of the East Potrillo Mountains horst. Clasts at Camel Mountain consist mostly of felsite, flow-banded rhyolite, and silicic ash-flow tuffs with a minor component of more mafic volcanic debris. In exposures in the East Potrillo Mountains, a wide variety of volcanic clasts are mixed with Lower Cretaceous and Permian detritus as well as with an occasional Precambrian granite cobble. In both areas clasts range in size from boulders to pebbles; bedding includes both planar and cross-bedded types. Cementation is strong in both areas, but the Camel Mountain strata are extensively silicified. Dips of strata are approximately 10 to 25 degrees.

Although contacts with older rocks are not exposed, the clast content of the fanglomerates indicates that they are younger than the Eocene–Oligocene volcanic section. They clearly correlate with strata of the lower part of the Santa Fe Group of the Las Cruces–Caballo area, specifically with the Hayner Ranch and Rincon Valley Formations of early to middle Miocene age (Seager et al., 1971; Seager and Hawley, 1973). The fanglomerate exposures are probably uplifted parts of the early rift Malpais basin, which gravity data indicate underlies a broad part of the southern West Potrillo Mountains area. The lower Santa Fe fanglomerates are overlain by Quaternary basalt or sand.

Tectonics

Although they are scarcely noticeable because of the great outpourings of nearly undeformed basalt, fault blocks of the Rio Grande rift dominate the structure of the West Potrillo Mountains beneath the basalt (Figs. 3 and 4). In addition, there is evidence for three older periods of significant deformation: mid-Wolfcampian, Early Cretaceous, and Laramide.

Mid-Wolfcampian deformation

The western flank of the West Potrillo Mountains is positioned between two well-documented uplifts of mid-Wolfcampian age: the Florida islands of Kottlowski (1960) to the west and the Moyotes uplift of Navarro and Tovar (1975) to the south. It is not surprising then that evidence for the mid-Wolfcampian episode of uplift and erosion exists in the West Potrillo Mountains.

Evidence for mid-Wolfcampian tectonism is stratigraphic. Lower Permian sedimentary rocks (Hueco–Colina) apparently unconformably overlie lower Paleozoic rocks in at least part of the Camel Mountain fault block, and they (Abo Formation(?)) overlie Precambrian granite in the Pemex No. 1 Moyotes well in northern Chihuahua (Navarro and Tovar, 1975; Thompson et al., 1978; Fig. 1). Regional isopachs and facies indicate that pre-Permian strata, including rocks of Pennsylvanian, Mississippian, and Devonian age, were deposited across the region (Greenwood et al., 1977), although the Florida uplift may have been emergent during at least part of the Pennsylvanian (Kottlowski, 1963). It seems likely then that the absence of pre-Permian strata in the Camel Mountain area can be attributed to uplift and erosion in mid-Wolfcampian time. The Florida–Moyotes uplift trend apparently is a major, ancestral Rocky Mountain, basement-cored uplift that trends northwesterly and extends for at least 60 mi from northern Chihuahua to the Deming area and beyond, where it is called the Burro uplift (Elston, 1958; Thompson, 1982).

Early Cretaceous deformation

Evidence for Early Cretaceous deformation comes from the Eagle Nest area. Coarse-grained arkose in the Lower Cretaceous Hell-to-Finish Formation suggests uplift and erosion of nearby Precambrian granitic terrane, possibly the fault block at Granite Hill. This Precambrian terrane may have been part of the Early Cretaceous rift shoulder of Mack (1987; Mack et al., 1986) or possibly an intrarift uplift. Mid-Wolfcampian erosion from the Florida–Moyote uplift may also have caused removal of some of the Paleozoic units from the Eagle Nest–Granite Hill area, whereas Permian and perhaps older Paleozoic strata may also have been eroded during the Early Cretaceous deformation.

Laramide deformation

Evidence for Laramide deformation in the West Potrillo Mountain region is based on outcrops in the East Potrillo Mountains and at Eagle Nest and Granite Hill. Folds and associated thrust faults in the East Potrillo Mountains involve Lower Cretaceous and Permian rocks, trend N30°W, and verge toward the northeast. Most thrust faults dip moderately westward and appear to originate in the cores of anticline–syncline pairs. Locally, however, Permian strata lie above Cretaceous rocks on thrust faults of possible regional extent. Structural relief due to both folding and faulting approaches 2,000 ft. The deformation projects northwestward beneath the West Potrillo Basalt where similar structures presumably exist in the subsurface. At Eagle Nest a thrust fault, which trends N20°W and dips moderately westward, has carried Permian carbonates northeastward above overturned Lower Cretaceous strata (Fig. 4). Both hanging-wall and footwall rocks are truncated by the thrust, but stratigraphic separation cannot be determined. The very coarse grained, Upper Cretaceous–lower Tertiary arkosic strata and conglomerate at Granite Hill also suggest Laramide basement-cored uplift and erosion at that area, only 1 mi east of the thrust faults and overturned folds at Eagle Nest.

Whether the Laramide thrusts and folds are examples of regional overthrusts (Drewes, 1978; Woodward and DuChene, 1982) or are marginal structures of basement-cored blocks (Seager and Mack, 1986; Seager et al., 1986) is not known. The general structural style may be interpreted in terms of either model. That basement was involved in at least some of the Laramide structures seems clear from the arkosic strata at Granite Hill.

Late Tertiary deformation

Early rift low-angle faults—A system of low-angle normal faults is also exposed in the East Potrillo Mountains (Seager and Mack, in press; Fig. 4). These faults offset Laramide structures and therefore are younger; they are older than the modern high-angle, range-boundary faults. Seager and Mack (in press) consider the faults to be of probable early Miocene age, formed during an early phase of extension in the Rio Grande rift. The system trends N30°W, dips generally NE, and may be projected northwestward beneath the West Potrillo basalts. Stratigraphic separation across the fault system, which consists of three or four major strands, is 1,650 ft.

This fault system has some of the characteristics of a detachment fault zone. Locally, at least, hanging-wall strata are more broken and rotated above low-angle sole faults than are footwall rocks. Also, long segments of the fault zone remain low angle (30° or less) after 25° of late Tertiary tilt is removed. These features suggest the fault zone may have been initiated as a low-angle detachment with tilted, listric, fault-bounded blocks active in the hanging wall. However, no mylonitic or metamorphic fabrics are present either within or below the fault zone; brittle deformation characterizes both hanging wall and footwall. If the fault zone is a detachment, it represents an upper crustal segment of comparatively small displacement.

Latest Tertiary and Quaternary fault blocks

Major late Tertiary and Quaternary fault blocks of the West Potrillo Mountains are shown on the tectonic map in Figure 3 and in the cross sections in Figure 4. The blocks were identified by their gravity signature (DeAngelo and Keller, 1988), by exposures around the perimeter of the West Potrillo basalt field, or by a combination of the two.

Robledo–East Potrillo uplift—The Robledo–East Potrillo uplift is the buried connection between the Robledo uplift to the north and the East Potrillo uplift to the south (Fig. 3). Whereas both of the exposed uplifts are horsts, their buried connection apparently is bounded only on the west by a major fault zone. This fault, the West Robledo fault, separates the uplift from the adjacent Akela and Malpais basins to the west. The fault is downthrown to the west and, at least along its exposed northernmost extent in the Robledo Mountains, has stratigraphic separation of approximately 2,500 ft. It can be traced from the western margin of the Robledo uplift southwestward and then southerly across the West Potrillo Mountains for a total distance of nearly 60 mi. Across the West Potrillo basalts the fault's position is marked by widely scattered scarps and, more clearly, by a steep gravity gradient of 30 mgal relief. The fault passes almost through the middle of the West Potrillo basalt field, and half or more of the Quaternary cinder cones in the field lie on or adjacent to the fault. The scarps in the basalt clearly indicate Quaternary movement on the fault, and the position of the cinder cones suggests that basaltic magma utilized fractures in the zone during its ascent to the surface.

Akela basin—Revealed both by gravity data and by the synclinal structure of exposed volcanic rocks, the Akela structural basin trends northwesterly, oblique to the West Robledo fault (Fig. 3). The central, deepest part of the basin appears to be a half graben bounded on the northeast by the Good Sight fault, which delineates the southwestern margin of the Good Sight–Sierra de las Uvas horst (Fig. 3). To the southeast, the basin becomes shallower and synclinal in form as evidenced by increasing Bouguer gravity values and by synclinal dips in Uvas Basaltic Andesite. The synclinal part of the basin terminates against and may be truncated by the West Robledo fault. Deepest parts of the basin probably contain thick basin fill, but the synclinal part is probably surfaced by Tertiary volcanic rocks, some of which crop out along the hinge. Most of the southeastern synclinal part of the basin is buried beneath Quaternary sand or basalt flows.

Malpais basin—Like the Akela basin, the Malpais structural basin has little or no surface expression. It is essentially hidden by sand and basalt.

The basin is clearly revealed by gravity data (DeAngelo and Keller, 1988). It is a north-trending graben, approximately 12 mi wide, that is bounded on the east by the West Robledo fault and on the west by a steep Bouguer gravity gradient interpreted to be a fault, the Malpais fault zone (Figs. 3 and 4). The basin has more than 30 mgl and 20 mgl relief on the east and west sides, respectively.

Although there are no exposures of basin fill within the graben, uplifted and exposed fanglomerate crops out on both the western and eastern bordering uplifts, at Camel Mountain and along the western edge of the East Potrillo horst, respectively. The deposits are tilted and faulted basin-fill deposits, probably Miocene in age, derived largely from Tertiary volcanic rocks. Exposed thickness in both areas is several hundred feet. Presumably the same deposits, possibly much thicker, occur in the deeper, buried parts of the Malpais basin. The older deposits within the graben, together with exposed sections of basin fill on adjacent uplifts, may constitute the fill of an early rift basin whose original extent was greater than the modern Malpais graben.

Camel Mountain uplift—The structurally high block that emerges from beneath the western margin of the West Potrillo basalt is the Camel Mountain uplift (Figs. 3 and 4). It is bounded on the west, north, and east by the Mesquite Lake, Akela, and Malpais basins, respectively. The uplift has relatively low topographic relief and is widely covered by sand, so that the surface expression of the uplift passes imperceptibly into the Akela and Malpais basins. Only a few bedrock islands project through the mantle of sand, and these, together with drill-hole data, were utilized to construct the stratigraphic column (Fig. 2). A block tilted eastward throughout much of its extent, the Camel Mountain uplift is a horst in its southern part.

The main boundary fault of the Camel Mountain uplift is the Camel Mountain fault. Downthrown to the west, the fault limits the western edge of the uplift as well as the east-

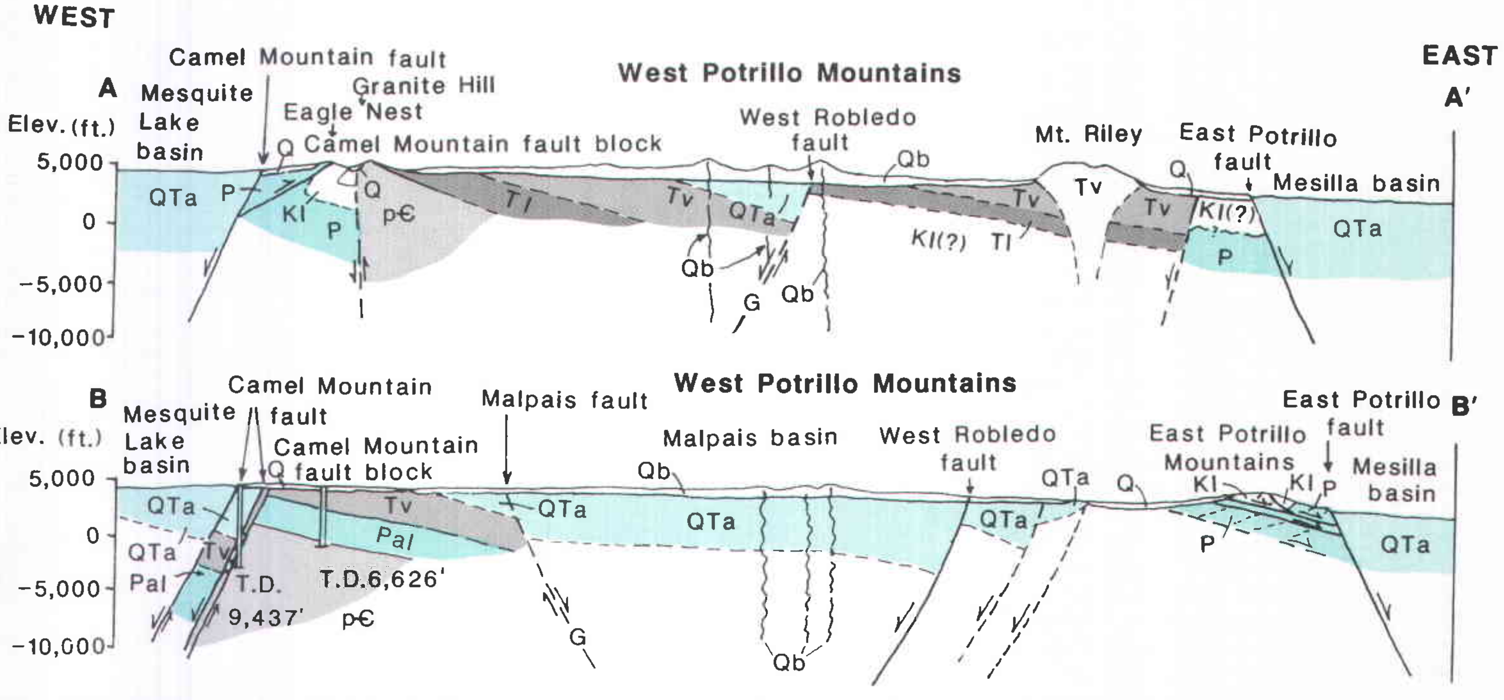

FIGURE 4—Sections across the West Potrillo Mountains showing, somewhat diagrammatically, interpretation of major subsurface structural features. Symbols also used in Figure 2; see Figure 3 for location of sections. **Q,** Quaternary alluvium; **Qb,** Quaternary basalt flows and cinder cones; **QTa,** Quaternary and Tertiary basin fill; **Tv,** Tertiary volcanics and intrusives; **Tl,** Upper Cretaceous and lower Tertiary Love Ranch Formation, Lobo Formation, and related rocks; **Kl,** Lower Cretaceous rocks; **P,** Permian carbonates; **Pal,** Paleozoic rocks, undifferentiated; **p-€,** Precambrian granite and related rocks.

ern margin of the complementary Mesquite Lake basin. The surface expression of the fault is the Camel Mountain escarpment (Fig. 1), a prominent late Quaternary scarp that extends at least 55 miles southward into Mexico (Reeves, 1969). Stratigraphic separation across the fault, estimated from the structural elevation of the top of Precambrian rocks in the Sunray and Skelly oil tests, which are on opposite sides of the fault, is approximately 2,200 ft.

Mesquite Lake basin—The Mesquite Lake structural basin lies to the west of the Camel Mountain uplift on the downthrown side of the Camel Mountain fault (Figs. 3 and 4). North trending, the basin extends southward into Mexico and westward to the vicinity of Columbus, New Mexico. To the north, it is separated from the Akela basin by a low gravity ridge. From available data, the Mesquite Lake basin appears to be a graben. Basin fill as much as 5,000 ft thick was penetrated in the Skelly well (Thompson, 1982) on the eastern edge of the basin adjacent to the Camel Mountain fault. This figure may be representative of the depth of the Mesquite Lake basin.

Summary of tectonic history

After deposition of lower and middle Paleozoic shelf carbonates, uplift and erosion along a northwest-trending axis took place in mid-Wolfcampian time (Thompson, 1982). Known as the Burro–Florida–Moyotes uplift (Thompson, 1982), it was part of the ancestral Rocky Mountain system and probably separated the Pedregosa basin on the southwest from the Robledo shelf and Orogrande basin on the east. Lower to middle Permian clastics and carbonates eventually buried the uplift.

During Early Cretaceous time, a major northwest-trending rift extended across the area from southwestern New Mexico into southeastern Arizona (Bilodeau and Lindberg, 1983; Mack et al., 1986). Deposition of Lower Cretaceous marine and nonmarine clastics and carbonates filled the rift. Clastic components were derived, at least in part, from the raised rim of Precambrian rocks and Paleozoic sediments located along the northern and northeastern margin of the rift (Mack et al., 1986). An exposure of Precambrian granite in this rim, or an intrarift fault block, in the Granite Hill area was possibly a source of coarse arkosic debris deposited in adjacent parts of the rift.

Laramide deformation in the West Potrillo Mountains area produced northwest-trending, east-vergent folds and associated thrust faults of modest (2,000–2,500 ft) structural relief. Whether these are part of a system of regional overthrusts or are boundary fault and fold zones of basement block uplifts is not clear. A basement-cored block uplift at Granite Hill can be inferred from thick, arkosic sedimentary beds of Laramide age there; similar block uplifts have been described in areas farther to the east, northeast, and west of the West Potrillo Mountains (Seager, 1973; Seager and Mack, 1986). Thin-skinned folding and thrusting has been inferred to the southeast in the Juarez Mountains on strike with the West Potrillo deformation (Lovejoy, 1972, 1980; Drewes, 1978).

During the late Eocene, Laramide uplifts were eroded and large volumes of coarse- to fine-grained detritus were transported into complementary basins. The volcanic content of these deposits increases upward, heralding the onset of major andesitic and silicic volcanism during Oligocene time. Emplacement of andesitic and silicic domes, andesitic lahars, silicic ash-flow tuffs, and andesitic to latitic lava flows was widespread, all accompanied by emplacement of associated plutonic rocks. By late Oligocene time, 27–28 Ma, widespread basaltic andesite flows, locally interbedded with thick fanglomerate, suggest that an active extensional stress regime had been established.

In early to middle Miocene time, during an early stage of extension in the Rio Grande rift, thick sequences of fanglomerate and associated rocks filled the Malpais basin located along the southwestern edge of the West Potrillo Mountains. Low-angle faults, possibly detachment faults of modest displacement, probably are the same age as the basin, and although they now are exposed in pre-basin rocks, they may have been associated with development of the basin.

Latest Tertiary and Quaternary fault blocks of the southern Rio Grande rift evolved during the latest Miocene after 10 Ma. Major faults such as the East Potrillo fault, West Robledo fault, Good Sight fault, Malpais fault, and Camel Mountain fault border the major structural blocks of the West Potrillo Mountains area. Quaternary movement is indicated by scarcely eroded scarps in Quaternary deposits on all except the Good Sight and Malpais faults. The rise of basaltic magmas along the West Robledo fault zone during the Quaternary produced an impressive alignment of cinder cones along the fault, and the associated West Potrillo Basalt flows buried a vast area of the underlying fault-block structure.

The cinder cones and lava flows today are known as the West Potrillo Mountains, but those volcanics are only a thin rock mantle that conceals a varied and complex rock record of volcanism, sedimentation, and repeated tectonism dating back to Precambrian time.

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Abstracts

New Mexico Geological Society

The New Mexico Geological Society annual spring meeting was held at New Mexico Institute of Mining and Technology (Socorro) on April 7, 1989. Following are abstracts from sessions given at that meeting. Abstracts from other sessions were printed in the May issue and will conclude in the November issue of *New Mexico Geology.*

Keynote speech

MID-TERTIARY VOLCANISM, EXTENSION, AND MINERALIZATION IN NEW MEXICO: WHAT HAVE WE LEARNED THESE PAST 40 YEARS? by *W. E. Elston*, Department of Geology, University of New Mexico, Albuquerque, NM 87131

Forty years ago, mid-Tertiary volcanic rocks were regarded as mere overburden on Laramide ore deposits. Beginning in 1950, the NMBMMR sponsored systematic studies which built a stratigraphic framework not yet complete. The Director, Eugene Callaghan, recognized the dominance of ignimbrites, a surprise because granitic magmas were then unpopular. The 1960's brought federal money, workers from the USGS and many universities, Oligocene K–Ar dates, resurgent cauldrons, connections between siliceous plutonism and volcanism, and plate tectonics. The 1970's and 1980's introduced petrogenetic models based on mineralogical, geochemical and isotopic studies, concepts of ductile extension, and $^{40}Ar/^{39}Ar$ dates. We now recognize dozens of ignimbrite cauldrons and andesite stratovolcanoes, results of partial melting of, respectively, lower crust and upper mantle, in an extending lithosphere. Many mid-Tertiary ore deposits are structurally controlled by cauldron ring fractures (e.g., Mogollon), as are some modern geothermal systems (e.g., Lightning Dock). Some ore deposits are also genetically controlled by cauldrons (e.g., Questa). Locations of volcanic centers are critical for evaluating hydrocarbon potential of certain sedimentary basins (e.g., Pedregosa basin). Oligocene volcanism in New Mexico was a small part of an "ignimbrite flareup" that buried ~1 million km^2 of western Mexico and southwestern USA under hundred to thousands of meters of ash and lava. It occurred during an "extensional orogeny" that may have doubled the width of the Basin and Range province. It is a major geological phenomenon of a type now recognized in many continents and periods (e.g., Permian of Eurasia, Quaternary of Sumatra and New Zealand).

Sedimentary, stratigraphy, and paleontology session

PULCHRILAMINA EARLY ORDOVICIAN LABECHIID STROMATOPOROID AND ITS MOUNDS, by *D. V. LeMone*, Department of Geological Sciences, The University of Texas at El Paso, El Paso, TX 79968

Pulchrilamina is a principal component of the bioherms of the Early Ordovician McKelligon Canyon Formation of the El Paso Group. It was first assigned in the late forties to the stromatolitic algae. Later workers not only excluded it from the stromatolitic algae but also from the stromatoporoids. In the late sixties it was classified as an uncertain affinity organism assigned to the hydrozoans of the coelenterate phylum. Webby, in a recent excellent reanalysis of the taxon, places it clearly within the labechiid stromatolites of the Phylum Porifera. Samples for this study, which were taken, in part, from the McKelligon Canyon stratotype, include a selection from Lechuguilla Mound where Toomey (1967) collected the holotype (USNM 155300) and fourteen paratypes. These Early Ordovician stromatoporoid sponge bioherms are observed to occur in nineteen cycles at the stratotype in the southern Franklin Mountains, El Paso County, Texas. The organism acts most effectively as a dominant, laminated binder (bindstone–boundstone) in the stressed climax stage. Similar occurrences of *Pulchrilamina* are recorded by Toomey and Hamm (1967) in the Kindblade Formation of the Early Ordovician Arbuckle Group Pre-Chazyan–White Rock, between the *Pulchrilamina* occurrences and the well-developed Middle and Upper Ordovician stromatoporoid, and are reported from North China and Malaysia.

CONODONT BIOSTRATIGRAPHY OF THE KELLY LIMESTONE (MISSISSIPPIAN), CENTRAL NEW MEXICO, by *S. T. Krukowski*, Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro, NM 87801

The Kelly Limestone (Mississippian) of central New Mexico is located in widespread outcrops along the western margins of the Rio Grande rift. It nonconformably overlies Precambrian igneous and metamorphic rocks and is unconformably overlain by the Pennsylvanian Sandia Formation. The lower Caloso Member consists of sandstones, shales, and various limestones. The Ladron Member disconformably overlies the Caloso and is composed mostly of crinoidal grainstones. The Caloso Member consists of a lower clastic facies, a middle silty lime mudstone facies, and an upper wackestone and packstone facies. The Ladron Member is also composed of three facies in ascending order: the crinoidal grainstone facies separated into upper and lower parts by the second facies, the "silver pipe," an argillaceous dolomitic mudstone named after its association with lead and silver ore deposits; and the third facies, the Bryozoan - *Pentremites conoideus* zone named after a conspicuous fossil fauna. Basal limestones of the Caloso Member have produced conodonts assigned to *Patrognathus variabilis, Polygnathus inornatus,* and *Bispathodus aculeatus plumulus* indicating upper *sulcata* Zone (early Kinderhookian). The top of the Caloso and lower Ladron Member have yielded diagnostic conodont faunas from upper *typicus* to lower *anchoralis-latus* Zones (early Osagean): *Gnathodus cuneiformis, Gnathodus delicatus, Gnathodus typicus* M1 and M2, *Polygnathus communis communis* and *Pseudopolygnathus oxypageous* M1 and M3. The Ladron Member produced conodonts throughout its thickness except for the "silver pipe" facies. The Ladron conodont fauna above the silver pipe consists of elements diagnostic of upper *texanus* Zone (upper Osagean): *Cloghergnathus* spp., *Gnathodus texanus, "Spathognathodus" deflexus,* and *Taphrognathus varians.* The top of the Ladron is assigned a latest Osagean–Meramecian age because it contains specimens belonging to the genus *Cavusgnathus.* The Caloso Member was determined to be Kinderhookian by early workers based on brachiopod faunas. It was later reassigned a middle Osagean age based on the endothyrids *Latiendothyra, Medioendothyra,* and *Tuberendothyra.* The Ladron Member was assigned to the late Osagean based on brachiopod and blastoid assemblages, and the first occurrences of the foraminifers *Prisella, Pseudotaxis,* and *Tetrataxis.* Results of this study have shown that the Caloso Member is early Kinderhookian at its base and early Osagean at the top. The lower crinoidal facies of the Ladron Member is early Osagean at its base to early Meramecian at the top. The disconformity between the two