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STRUCTURAL AND STRATIGRAPHIC EVIDENCE FOR THE LARAMIDE (EARLY TERTIARY) BURRO UPLIFT IN SOUTHWESTERN NEW MEXICO

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Abstract—The late Laramide (Paleocene-Eocene) Burro uplift in the vicinity of the Florida Mountains and southern Cooke's Range, southwestern New Mexico, was a west–northwest-trending, basement-cored uplift that consisted of at least three major segments. The southern segment was uplifted by the southward-dipping, high-angle, right-lateral oblique-slip south Florida Mountains reverse fault that brought Precambrian-Cambrian crystalline basement over Paleozoic sedimentary rocks. Three levels of imbricate thrusts within Paleozoic sedimentary rocks rooted into and were the result of movement on the south Florida Mountains fault. The southern segment was bordered on the north by a closed, intra-uplift basin that was floored by less than 200 m of locally derived alluvial-fan and lacustrine detritus of the Lobo Formation. The Lobo Formation thins northward and pinches out against the basement-cored northern portion of the central segment. The northern segment consisted of a complementary basin that contained at least 350 m of the Lobo Formation. Deposition in the northern basin was by alluvial-fan and fluvial processes. The presence of basement-cored blocks separated by largely undeformed basins and evidence of only a few kilometers of crustal shortening suggest that the tectonic style of the Laramide Burro uplift is more analogous to the Laramide Rocky Mountain foreland than to the Sevier overthrust belt.

INTRODUCTION

West–northwest-trending compressional structures in the Florida Mountains provide important, although controversial, data concerning the style of Laramide (latest Cretaceous-early Tertiary) tectonism in southwestern New Mexico. The structures in the Florida Mountains and other areas in southeastern Arizona and southwesern New Mexico have been interpreted to represent a segment of the Cordilleran overthrust belt that connects the Sevier and Mexico fold and thrust belts (Fig. 1a; Corbitt and Woodward, 1973; Drewes, 1978, 1982; Woodward and DuChene, 1981). The Florida Mountains were considered to be on the northern edge of the overthrust belt by Corbitt and Woodward (1973), Drewes (1978) and Woodward and DuChene (1981), although Drewes (1982) subsequently placed the northern edge of the overthrust belt south of the Florida Mountains (Fig. 1a). Within the context of the overthrust model, there is disagreement concerning the role of crystalline basement and the magnitude of displacement along the faults. Corbitt and Woodward (1973) and Woodward and DuChene (1981) proposed that crystalline basement was not involved in the thrusting, and, more specifically, that plutonic rocks involved in compressional faults in the Florida Mountains are Mesozoic, not Precambrian or Cambrian, in age, an interpretation challenged by Clemons (1982a). In contrast, Drewes (1978) pointed out that the overthrust belt in southeastern Arizona and southwestern New Mexico may be unique because of basement involvement. Furthermore, Drewes (1978, 1982) estimated the distance of transport of thrusts in southeastern Arizona to be no less than 18 km and to perhaps be as much as 100 km, whereas Woodward and DuChene (1981) suggested that total displacement on thrusts in southwestern New Mexico is only a few kilometers.

The overthrust model in southwestern New Mexico has been recently re-examined in light of new structural and stratigraphic data, including mapping on the scale of 1:24,000 in the Florida Mountains by Clemons (1982b, 1984, 1985) and Clemons and Brown (1983). The Florida Mountains are a key in the controversy because they contain one of the few well exposed segments of the northwest-trending structural zone under debate. Elsewhere in southwestern New Mexico the hypothetical overthrust belt is mostly covered by basin fill and mid- to late Tertiary and Quaternary volcanics.

The results of these studies suggest that Laramide deformation in southwestern New Mexico was characterized by three west–northwest-trending, basement-cored block uplifts, which were separated by largely undeformed intermontane basins (Fig. 1b; Seager, 1983; Brown and Clemons, 1983; Seager and Mack, 1986; Seager et al., 1986). This tectonic style has close affinity to the Laramide Rocky Mountain fo-

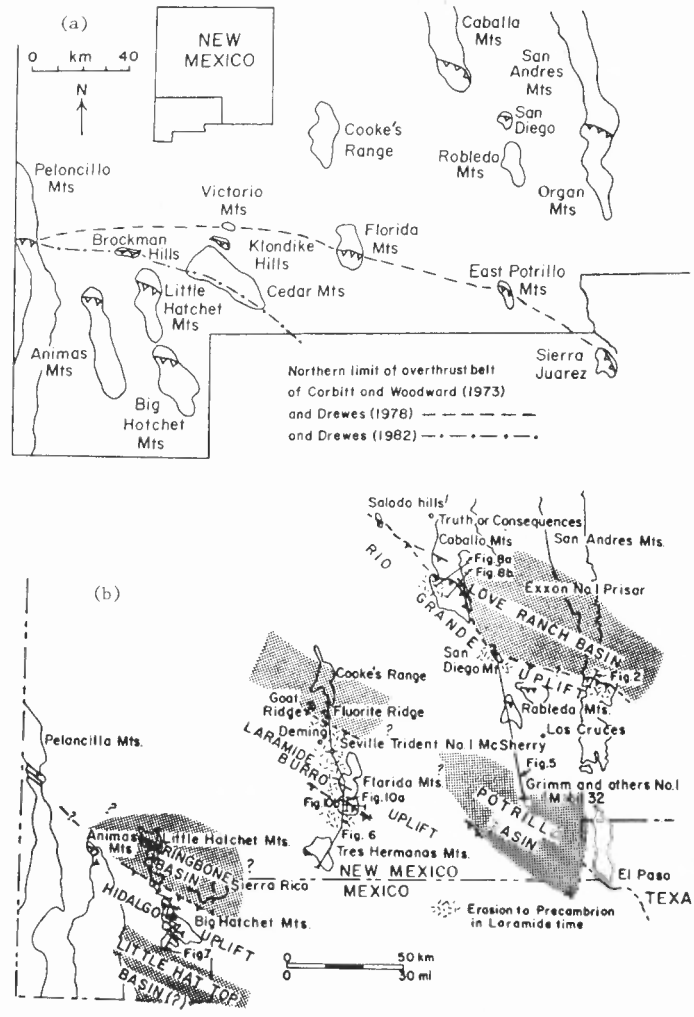


FIGURE 1. **A**, Mountain ranges in southwestern New Mexico that display Laramide structures, shown with thrust fault symbol, or have Laramide-age sedimentary rocks. Also shown is the approximate position of the northern edge of the overthrust belt of Corbitt and Woodward (1973) and Drewes (1978, 1982). **B**, Tectonic model of Seager (1983) and Seager and Mack (1986) that interprets the data above in terms of three major basement-cored block uplifts separated by intermontane basins.

reland (Prucha et al., 1965; Gries, 1983). In this model, the Florida Mountains occupies a position along the southern flank of a much larger segmented uplift, called the Larmide Burro uplift by Seager (1983) and Seager and Mack (1986). The purpose of this paper is to present the structural and stratigraphic evidence in support of the block uplift model for the area in and adjacent to the Florida Mountains. Structural relations in the Florida Mountains suggest complex Laramide compressional deformation characterized by: (1) high-angle reverse faulting, (2) low-angle thrusting, localized overturned folds, (3) extensive tectonic brecciation and (4) examples of stratigraphic elimination along thrust faults.

LARAMIDE BURRO UPLIFT

Rocks exposed in the Florida Mountains and in the southern Cooke's Range, as well as subsurface data near Deming, provide a north–south, cross-sectional view of the Laramide Burro uplift. Two different types of data are used in the reconstruction of the uplift: compressional structures exposed in the southern Florida Mountains, and the distribution of thickness and facies of the Lobo Formation in the Florida Mountains and southern Cooke's Range (Fig. 2).

Several lines of evidence suggest that the structures in the southern Florida Mountains are Laramide in age. First, they trend at near right angles to and are crosscut by Basin and Range normal faults. Secondly, these structures include reverse and thrust faults and complementary folds that are clearly of compressional, not extensional, origin. Finally, the structures involve rocks ranging in age from Precambrian to early Tertiary, but do not involve late Eocene and younger volcanic and sedimentary rocks.

The Lobo Formation was originally defined by Darton (1916) for exposures of conglomerate, sandstone, siltstone and shale in the Florida Mountains, and was subsequently misapplied in Luna County to other conglomeratic red beds of Permian and Early Cretaceous age (see Lemley, 1982, for a review). Paleomagnetic data of Lemley (1982) indicate that the Lobo Formation in the Florida Mountains is probably early Tertiary (late Paleocene and Eocene) in age. Subsequently, the name Lobo Formation was applied in the southern Cooke's Range to lithologically similar rocks, which were originally mapped as the Starvation Draw member of the Rubio Peak Formation (Clemons, 1982c; Clemons and Brown, 1983).

The integration of structural and stratigraphic data suggest that the Laramide Burro uplift consisted of at least three major segments (Fig. 3). The southernmost segment was an uplifted block that was bordered on the north by reverse and thrust faults exposed in the southern Florida Mountains. The central segment constituted an intra-uplift basin that was floored by a maximum of 200 m of the Lobo Formation. The Lobo Formation thinned northward and eventually pinched out against the topographically higher northern portion of the central segment, which was bordered on the north by a complementary basin containing as much as 350 m of the Lobo Formation. A more detailed discussion of these tectonic elements follows.

Structural style in the southern Florida Mountains

The most prominent structural feature in the Florida Mountains is the south Florida Mountains reverse fault (SFMF), which displaces Cambrian granite and hornfels against Cambrian syenite and Ordovician to Permian strata (see Figs. 1:4.5a and b, this guidebook). Before Basin and Range tilting the SFMF had a strike of N50W and dipped 85° southwest. The Paleozoic section (1250 m) represents a minimum stratigraphic separation on the fault. Movement on the SFMF is interpreted

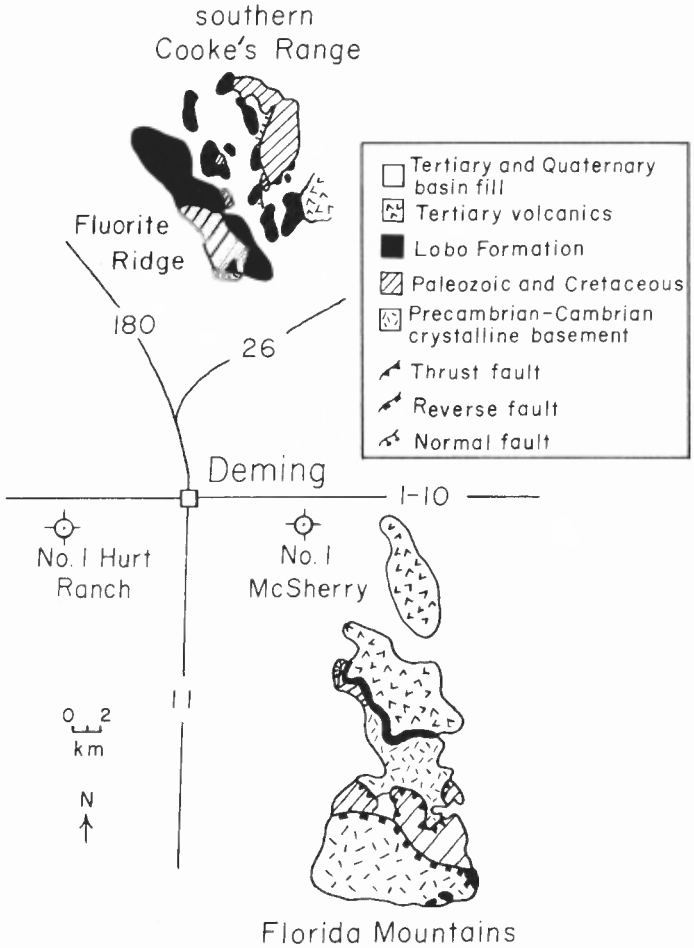


FIGURE 2. Location and general geology of the Florida Mountains and southern Cooke's Range, adapted from Clemons (1982a, b, 1984, 1985) and Clemons and Brown (1983).

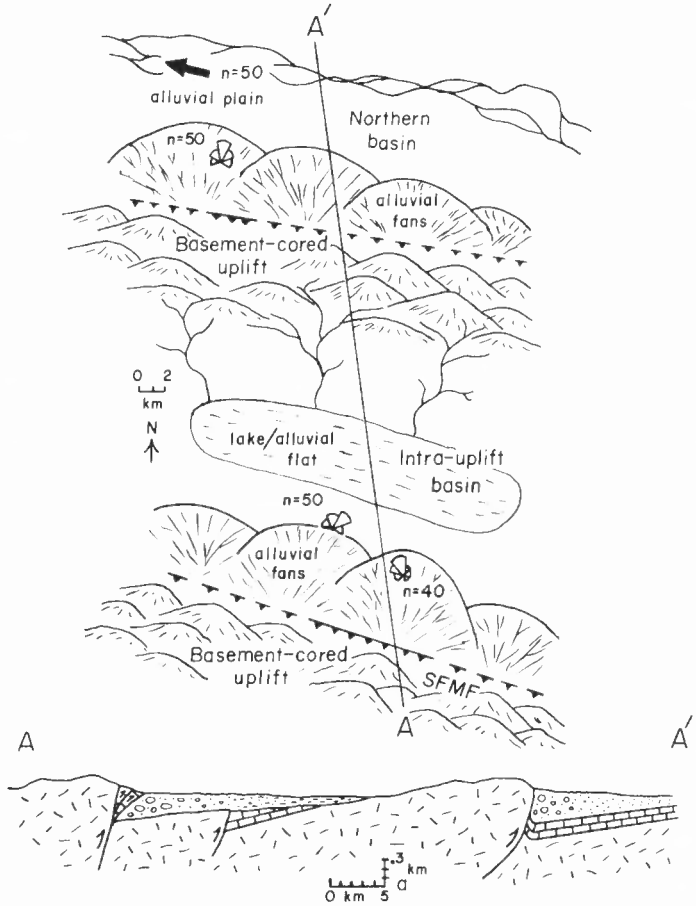


FIGURE 3. Paleogeographic and paleotectonic interpretation of the Laramide Burro uplift. Paleocurrent roses represent cobble imbrications and the paleocurrent arrow represents the mean of trough crossbed measurements following the technique of DeCelles et al. (1983).

to have produced three levels of imbricate thrusts within the Paleozoic rocks: the Victorio, Gym Peak and Mahoney thrusts are names given to the lower, middle and upper levels, respectively (Brown and Clemons, 1983).

The low-angle faults are controversial in that most have younger over older stratigraphic displacements (Fig. 4a). Considerable evidence was presented by Brown (1982) to document the low-angle faults as thrust faults. The thrusted recumbent fold in the steep northern cliffs of Gym Peak superposed older rocks on younger rocks (Fig. 4b).

The Victorio thrust sheet is an intensely deformed, locally brecciated, complex sheet which placed younger Paleozoic rocks over older autochthonous Paleozoic strata and Cambrian plutonic rocks along a highly variable fault surface. Tectonic elimination is pervasive along the thrust surface with strata ranging from Lower Ordovician middle El Paso beds to Silurian Fusselman Dolomite resting on Cambrian syenite basement. The present position of this thrust sheet, north of and below the Gym Peak thrust, suggests that rocks of this sheet may have had their source in the present location of the Gym Peak thrust and were simply pushed northeastward to make room for the incoming Gym Peak thrust slice (Fig. 4a).

The Gym Peak thrust also placed younger strata over older strata except in the northern cliffs of Gym Peak, where a large recumbent drag fold developed with upper and lower limbs broken by thrust faults; the Montoya Formation is clearly repeated three times with the middle section overturned (Fig. 4b). The fold attitude and closure is consistent with generation by a northeast-yielding Gym Peak thrust with an estimated 600 m of horizontal displacement. Within the Gym Peak thrust there are a number of normal faults which trend northeasterly and are truncated at the top by the Mahoney thrust and at the base by the Gym Peak thrust (Fig. 4a).

The Mahoney thrust is the highest level of thrusting and displaced younger strata over older strata. The thrust typically truncates underlying structures suggesting that latest movement postdated movement of the lower thrust levels. This configuration is analogous to an experimental study by Sanford (1959), which showed that vertical uplift caused successive imbricate thrust slices to develop with higher levels having the most recent movements.

The SFMF may also have a significant strike-slip component. Juxtaposition of granite in the hanging wall south of the reverse fault and syenite north of the fault is difficult to explain by simple uplifting of the granite. Attitudes of Paleozoic strata south of Gym Peak and in Mahoney Park indicate possible drag folding associated with right-lateral movement along the SFMF. This fault is near vertical throughout the 600 m of exposed relief. There is considerable tectonic brecciation along the fault zone and there are several similar anastomosing faults in the southern Florida Mountains (typical of strike-slip faults). A series of east–northeast-trending rhyolite dikes (see Fig. 1:45.5b, this guidebook) may represent intrusion of tensional fractures generated by right-lateral movement along the SFMF.

Intra-uplift basin

The southern segment of the Laramide Burro uplift was bordered on the north by an intra-uplift basin that was floored by syn- and post-tectonic siliciclastic rocks of the Lobo Formation (Fig. 3). The Lobo

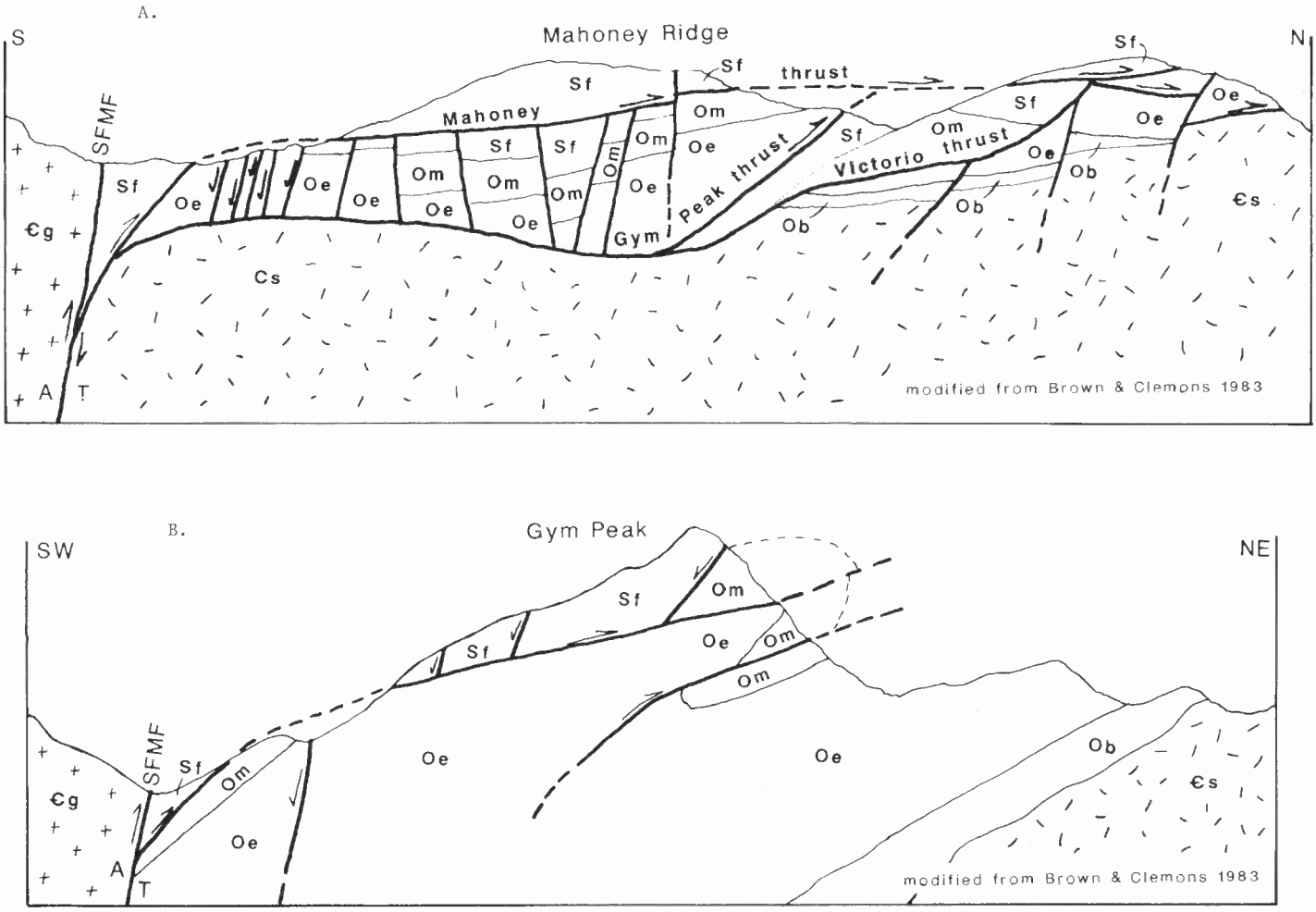


FIGURE 4. Diagrammatic cross sections north and northeast of the south Florida Mountains fault (SFMF). Cg: Upper Cambrian granite; Cs: Upper Cambrian syenite; Ob: Bliss Formation; Oe: El Paso Formation; Om: Montoya Formation; Sf: Fusselman Dolomite. **A,** Three levels of thrusting on Mahoney Ridge. **B,** Gym Peak thrust breaching overturned anticline on northeast slope of Gym Peak.


A


B


C


D


E


F


G


H

unconformably overlies rocks ranging in age from Precambrian to Permian and varies in thickness from 0 to 200 m. The thickest section, exposed in the southeastern part of the Florida Mountains, overlies the Permian Hueco Formation and is crosscut by the south Florida Mountains reverse fault, indicating a syn-tectonic origin (Fig. 2). Along the outcrop belt in the northern Florida Mountains, the Lobo is about 180 m thick and does not appear to be involved in Laramide deformation (Fig. 2). Sections were measured at Capitol Dome along the northwestern edge of the outcrop belt, at Lobo Draw along the southeastern edge of the outcrop belt and at a location roughly half-way between these two, called the north-central section. Subsurface data in the vicinity of Deming indicate that the Lobo is thin (90 m) or absent (Fig. 2; Clemons, 1986).

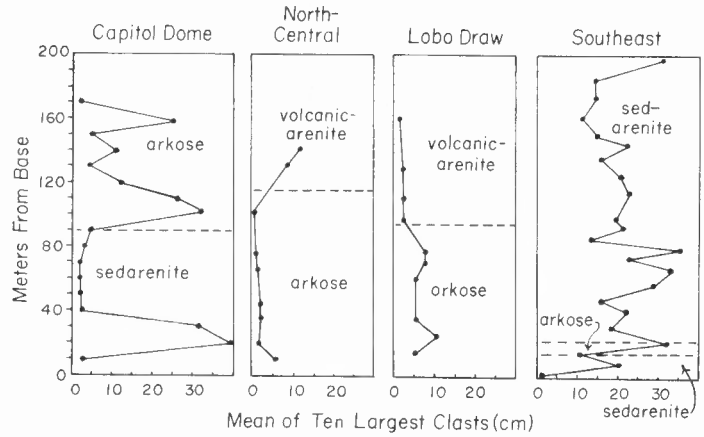


FIGURE 6. Grain size trends in the Lobo Formation in the Florida Mountains. Clast size is the length of the long (A) axis. Also shown are the stratigraphic position of sandstone and conglomerate petrofacies.

Depositional environments

The Lobo Formation in the intra-uplift basin was deposited in alluvial-fan and lacustrine environments. The most proximal alluvial-fan facies is exposed in the southeastern section and consists primarily of cobble and boulder conglomerate with subordinate sandstone and shale. The lower 25 m of this section is characterized by beds up to four m thick of grain-supported pebble, cobble and boulder conglomerates that display an erosional base. Other conglomerates, ranging from 0.5 to three m thick, are massive to poorly bedded, extremely poorly sorted and matrix-supported (Fig. 5a). Also present are poorly exposed, laminated pebbly coarse sandstones interbedded with red shales. The grain-supported conglomerates are water-laid and probably were deposited in fanhead channels. In contrast, the matrix-supported conglomerates are most likely debris flows (Bull, 1972; Mack and Rasmussen, 1984). Pebbly sandstone and shale may represent interchannel or fine-grained channel-fill deposits. The upper 175 m of the southeastern section consists of a monotonous sequence of medium- to thick-bedded, grain-supported, cobble and boulder conglomerate with little or no interbedded sandstone (Fig. 5b). These conglomerates were probably deposited by a series of coalescing shallow gravel channels (Miall, 1985). The proximal-fan section is arranged into a series of coarsening-upward and fining-upward sequences that range in thickness from 10 to 55 m (Fig. 6). These sequences probably reflect episodes of tectonic uplift and subsequent quiescence in the adjacent source terrane, although the smaller-scale sequences may be autocyclic in origin (Steel and Wilson, 1975).

The Lobo Formation fines rapidly northward, and along the northern outcrop belt consists predominately of medium sandstone and siltstone with subordinate conglomerate, shale and limestone. At Capitol Dome, the Lobo Formation unconformably overlies the Ordovician Montoya Formation and the basal 15 m consists of interbedded conglomerate and gray and purple mottled shale that locally have vertically elongated calcareous nodules and tubules of probable pedogenic origin (Fig. 5c). Throughout the northern outcrop belt the dominant facies is thinly bedded, horizontally laminated, or less commonly trough crossbedded or ripple laminated, fine and medium sandstone and siltstone. Parting lineation is commonly associated with horizontal laminations. Lenses (<20 cm thick) and broad, shallow channels (<1 m thick) of granule and pebble conglomerate are commonly intercalated with the sandstone and siltstone (Fig. 5d). Burrows, root traces and small (<2 cm) calcareous nodules are locally abundant, especially in the finer grained strata. Thicker conglomerate beds (up to 4 m) display a channel morphology and consist of grain-supported, imbricated pebbles and cobbles. Imbrication measurements indicate northwestward or northeastward transport (Fig. 3). Also present are a few thin (<1.5 m) beds of reddish, matrix-supported pebble conglomerate (Fig. 5e), silty carbonate mudstone containing a few ostracods and gastropods and laminated gray sandstone and shale (Fig. 5f).

The Lobo Formation along the northern outcrop belt was deposited on the distal portion of an alluvial fan and in a lacustrine environment. The laminated sandstones and siltstones with intercalated conglomerates were deposited by shallow, high-velocity currents and probably represent sheetflood deposits (Bull, 1972; Mack and Rasmussen, 1984). The thicker conglomerates were deposited in broad channels that dissected the fan surface, and the matrix-supported conglomerates represent distal debris-flow deposits (Bull, 1972). Silty carbonate mudstone and the laminated gray sandstones and shales were deposited in shallow lakes beyond the toe of the fan. Relatively slow sedimentation rates allowed pedogenic reworking of some of the sediment, resulting in root traces and caliche nodules.

Along the northern outcrop belt of the Florida Mountains vertical changes in grain size do not correlate well between sections (Fig. 6). At Capitol Dome, two coarsening-upward and fining-upward sequences are present, whereas the Lobo Draw section displays a single fining-upward sequence. The north-central section is similar to the Lobo Draw section, except for a slight coarsening at the top (Fig. 6).

Provenance

Examination of 38 thin sections from the northern outcrop belt, as well as cobble and boulder counts from the southeastern section, indicate that the Lobo Formation in the Florida Mountains can be separated into three petrofacies: sedarenite, arkose and volcanicarenite (Fig. 6). The sedarenite petrofacies is characterized in thin section by an abundance of monocrystalline quartz, chert and carbonate rock fragments. Also present are minor amounts of pelitic rock fragments, polycrystalline quartz and feldspar. In the gravel-sized fraction, the sedarenite petrofacies is composed of clasts of limestone, dolomite, sandstone and chert. The suite of detrital grains reflects derivation from sedimentary source rocks, probably Paleozoic cherty carbonates, sandstones and shales.

The arkose petrofacies has, in addition to the grain types described

FIGURE 5. Lithofacies of the Lobo Formation. **A,** Debris-flow conglomerate composed of clasts of sedimentary rocks, granite and gneiss in the lower part of the southeastern section of the Florida Mountains; pen is 15 cm long. **B,** Grain-supported pebble and cobble conglomerate composed of sedimentary clasts in the upper part of the southeastern section, Florida Mountains; hammer is 25 cm long. **C,** Calcareous nodules and tubules interpreted to be pedogenic caliche near the base of the Capitol Dome section, Florida Mountains; hammer is 25 cm long. **D,** Laminated sandstone and lenses of granule and pebble conglomerate deposited by sheetfloods in the Capitol Dome section, Florida Mountains; pen is 15 cm long. **E,** Matrix-supported granule and pebble conglomerate representing a distal debris flow, Capitol Dome section, Florida Mountains; pen is 15 cm long. **F,** Thin-bedded, rippled and laminated sandstone and laminated gray shale of lacustrine origin, Capitol Dome section, Florida Mountains; hammer is 25 cm long. **G,** In situ boulder of granite in the proximal debris-flow facies along the southern flank of Fluorite Ridge; Jacob's staff is 1.5 m long. **H,** Matrix-supported cobble conglomerate of debris-flow origin along the southern flank of Fluorite Ridge; notebook is 19 cm long.

for the sedarenite petrofacies, greater than 10% feldspar, including microcline, orthoclase, perthite and plagioclase. Also present are quartzofeldspathic rock fragments and low-grade metamorphic rock fragments. In the gravel-sized fraction, the arkose petrofacies is defined by the first appearance of granitic and gneissic clasts. The most likely source for the feldspar and granitic/metamorphic rock fragments in the arkose petrofacies is the Precambrian-Cambrian crystalline basement. Indeed, some gravel-sized clasts can be directly correlated with basement rocks exposed today in the Florida Mountains.

The volcanicarenite petrofacies is only present in the Lobo Draw and north-central sections, and is defined by the appearance of volcanic rock fragments that are composed primarily of plagioclase and have microlitic and porphyritic textures. Although never exceeding 15% of the grain population, the volcanic rock fragments indicate the presence, at least in small amounts, of andesitic volcanic rocks in the Florida Mountains. Because no pre-Lobo volcanic rocks are exposed today in the vicinity of the Florida Mountains, the andesites are assumed to have been coeval with the upper part of the Lobo Formation and probably were precursors to the extensive late Eocene andesitic volcanism of the Rubio Peak Formation (Clemons, 1982b, 1984, 1985; Clemons and Brown, 1983).

The upsection change from sedarenite to arkose petrofacies in the Capitol Dome and southeastern sections reflects unroofing of the crystalline core of the southern segment of the Laramide Burro uplift. In both cases, the change in petrofacies also corresponds to a coarsening-upward sequence, suggesting accelerated erosion in the source area and fan progradation. The fact that the Lobo Draw and north-central sections begin with the arkose petrofacies suggests that either these sections were deposited after initial unroofing of the crystalline core of the uplift or that they were derived from a region of the uplift lacking Paleozoic cover rocks. The former is supported by the fact that the arkose petrofacies corresponds to a fining-upward sequence. In the southeastern section, the unroofing of the basement was followd by a return to sedimentary source rocks and a significant change in grain size, implying complete reorganization of the alluvial fan. This may have been accomplished by overlap of adjacent fans or by a change in the drainage basin of the fan due to strike-slip movement along the south Florida Mountains fault system. The change from arkose to volcanicarenite petrofacies does not appear to be a response to a major tectonic event, because at the Lobo Draw section the petrofacies boundary is within a fining-upward sequence (Fig. 6). However, in the north-central section the volcanicarenite petrofacies is associated with a slight coarsening.

Summary

There are four lines of evidence to support an intra-uplift origin for the Lobo basin in the Florida Mountains: (1) the stratigraphic section is much thinner (<200 m) than in other intermontane basins in southwestern New Mexico (Seager, 1983; Seager and Mack, 1986), (2) the Lobo Formation overlies Precambrian and Paleozoic rocks, implying deep levels of erosion prior to deposition. In other intermontane basins in southwestern New Mexico, Laramide siliciclastic rocks overlie Cretaceous rocks, suggesting little erosion prior to deposition, (3) alluvial-fan and lacustrine environments and the lack of a through-going fluvial system indicate a closed basin and (4) the predominance of locally-derived detritus also supports a closed basin.

Northern basin

The boundary between the northern edge of the Laramide Burro uplift and the complementary northern basin is constrained solely by facies and grain size data from the Lobo Formation. Along the southwestern flank of Fluorite Ridge in the southern Cooke's Range a fault-bounded outcrop of the Lobo Formation unconformably overlies lower Paleozoic rocks and consists of boulder conglomerate containing granitic and gneissic clasts up to four m long (Fig. 5g). The Lobo Formation fines rapidly and systematically north–northeastward, and in the northernmost outcrops the maximum clast size is only about 50 cm. The extremely coarse grain size of the conglomerate exposed along the southwestern flank of Fluorite Ridge and the northward decrease in grain size suggest that the northern boundary of the Laramide Burro uplift was located no more than a few kilometers to the south of Fluorite Ridge (Fig. 3). Moreover, the predominance of granitic and gneissic clasts can best be explained if the northern part of the uplift was cored by crystalline basement. Unfortunately, the structural style of the northern end of the uplift cannot be determined, because of the lack of outcrops.

Depositional environments

The coarse conglomerate exposed along the southwestern flank of Fluorite Ridge lacks bedding, has no evidence of systematic size variations and locally is matrix-supported by reddish-brown, sandy mudstone (Fig. 5h). These characteristics indicate deposition by debris flows on the proximal part of an alluvial fan (Bull, 1972; Mack and Rasmussen, 1984). The lower half of the Lobo Formation in the northern outcrops of the southern Cooke's Range unconformably overlies the Cretaceous Sarten or Colorado Formations and is composed of grain-supported, imbricated pebble, cobble and boulder conglomerate and interbedded trough crossbedded and horizontally laminated, pebbly coarse sandstone that were probably deposited by braided streams and sheetfloods on the midfan or distal fan (Bull, 1972; Mack and Rasmussen, 1984). Imbrication measurements indicate northeastward sediment transport, a direction consistent with the trend of grain size decrease (Fig. 3).

The upper half of the section in the central and northern outcrop belt consists of fluvial rocks that can be separated into four lithofacies: conglomerate and coarse sandstone facies, red mudstone facies, interbedded sandstone and mudstone facies and fine sandstone facies. The conglomerate and coarse sandstone facies exists in beds 1.5 to 11 m thick and is composed either entirely of grain-supported pebble and cobble conglomerate or of conglomerate that fines upward to very coarse and coarse sandstone. The beds have an erosive base and in some cases display channel morphology. Trough crossbeds and horizontal laminations are common in the sandier portions of the facies.

The red mudstone facies is sandy and micaceous, commonly displays blocky weathering and locally contains small (<2 cm), irregularly-shaped calcareous nodules. The red mudstone varies in thickness from a few meters to 12 m. The interbedded sandstone and mudstone facies is characterized by beds of very fine- to fine-grained sandstone and red mudstone alternating on a scale of 20 to 80 cm. Sandstone beds may be massive, horizontally laminated or rippled laminated and occasionally burrowed. Beds of the sandstone and mudstone facies range in thickness from a few meters to eight m and are commonly associated with the red mudstone facies. The least common facies is the sandstone facies, which consists of 1.5- to two-m-thick beds of very fine- and fine-grained sandstone that exhibit horizontal laminations or asymmetrical ripple laminations. The sandstone beds have sharp upper and lower contacts and are commonly associated with the red mudstone facies.

The conglomerate and sandstone facies was deposited in fluvial channels. The lack of lateral accretion foresets suggests that meandering and point-bar deposition were not important processes (Miall, 1985). The lateral continuity of the beds and the coarse grain size support a braided channel model. Trough crossbed paleocurrent data collection, following the technique of DeCelles et al. (1983), indicates west–northwestward sediment transport, a direction parallel to the presumed axis of the basin and perpendicular to alluvial-fan paleocurrents (Fig. 3). The red mudstone and interbedded sandstone and mudstone facies were deposited from suspension and by low-velocity traction currents on the floodplain. The floodplain was relatively stable for long periods, indicated by the thickness of individual units, and the red color suggests an oxidizing environment. The small calcareous nodules may be caliche (Gile et al., 1981). The presence of sandstone in the interbedded sandstone and shale facies indicates a close proximity to the main channels. A crevasse-splay origin for the fine sandstone facies is suggested by the thinness of each unit, by the association with other floodplain facies and by the predominance of low-velocity sedimentary structures.

Provenance

The Lobo Formation in the northern basin can be divided into a lower arkose and an upper volcanicarenite petrofacies, based on examination of eight thin sections and several hundred cobble-boulder counts. The arkose petrofacies is composed of subequal amounts of monocrystalline quartz and feldspar, including both K-feldspar and plagioclase. Small amounts of quartzo-feldspathic rock fragments, polycrystalline quartz, chert, peletic rock fragments and metamorphic rock fragments are also present. For the gravel-sized fraction, the arkosic petrofacies is characterized by granitic and gneissic clasts, but carbonate, red siltstone, quartz sandstone and chert are also present. These detrital grains suggest derivation primarily from crystalline basement and secondarily from Paleozoic sedimentary rocks.

The volcanicarenite petrofacies consists of oscillatory zoned plagioclase and volcanic rock fragments exhibiting microlitic and porphyritic textures. Also present in small quantities is monocrystalline quartz, perthite and quartzo-feldspathic rock fragments. The principal source was andesitic volcanic rocks, but perthite and quartzo-feldspathic rock fragments also indicate a contribution from the crystalline basement. The volcanicarenite petrofacies is restricted to rocks of fluvial origin.

There is no evidence in the northern basin of an unroofing sequence. Although sedimentary clasts and grains are present in the arkose petrofacies, feldspars are common at the very base of the section. The absence of an unroofing sequence may be due to the fact that the Paleozoic cover was thin along the northern end of the uplift or was absent altogether. Other possibilities are that detritus derived from initial erosion of the Paleozoic cover was transported out of the basin during its early history, or the sedimentary-derived detritus was cannibalized by later uplift.

The dominant source of sediment for the upper part of the section was andesitic volcanic rocks. The volcanic contribution in the northern basin is much greater than in the intra-uplift basin. Although volcanic detritus dominated, basement detritus was still being supplied to the basin from the northern end of the Laramide Burro uplift throughout deposition of the Lobo Formation.

Summary

The northern basin is interpreted to be an intermontane basin, analogous to the Love Ranch and Potrillo basins of Seager (1983) and Seager and Mack (1986) (Fig. 1b), and contrasts sharply with the intra-uplift basin: (1) the Lobo Formation in the northern basin is almost twice as thick as in the intra-uplift basin, (2) the Lobo Formation in the northern basin unconformably overlies Cretaceous rocks, implying little erosion prior to deposition, (3) the northern basin has evidence of an axial fluvial system, which may indicate a more open basin and (4) the abundance of volcanic detritus suggests that the fluvial system drained a much larger area than that of the intra-uplift basin.

Southern margin

The southern flank of the Laramide Burro uplift is not well constrained because of lack of outcrops and subsurface data. South of the south Florida Mountains reverse fault, a thin veneer of Lobo conglomerate overlies Cambrian crystalline basement. The next exposure of pre-middle Tertiary rocks is about 20 km to the south–southwest of the Florida Mountains in the Tres Hermanas Mountains. At the western edge of the Tres Hermanas, dolomite that has recently been identified as Permian in age (Thompson, 1982) is thrust over conglomerate of unknown age. The conglomerate has previously been described as Lower Cretaceous (Kottlowski and Foster, 1962), but more closely resembles the Lobo Formation (Seager and Mack, 1986). Because of the uncertainty of the age of the conglomerate, its significance to the Laramide Burro uplift remains in doubt.

DISCUSSION

West–northwest-trending reverse and thrust faults and folds and associated lower Tertiary conglomerates provide strong evidence of Laramide deformation in southwestern New Mexico. However, two contrasting models have arisen concerning the style of this deformational event: (1) overthrust model, in which the deformation in southwestern New Mexico is analogous to and perhaps a continuation of the Sevier fold-thrust belt (Corbitt and Woodward, 1973; Drewes, 1978, 1982; Woodward and DuChene, 1981) and (2) foreland model, in which the deformation in southwestern New Mexico is analogous to and coeval with discrete basement-cored block uplifts of the central and northern Rocky Mountains (Seager, 1983; Brown and Clemons, 1983; Seager and Mack, 1986; Seager et al., 1986).

There are several features, other than age and location, that distinguish between the Sevier fold-thrust belt and the Laramide broken foreland. The fold-thrust belt is thin-skinned, and although crystalline basement may be involved in the hinterland or as small slivers, for the most part deformation is restricted to sedimentary rocks that overlie the crystalline basement (Royse et al., 1975; Harrison et al., 1980). In contrast, deformation in the foreland involves the crystalline basement, and in most cases cover rocks were eroded and the basement was exposed in the core of the block uplifts (Prucha et al., 1965; Gries, 1983). The geometry of the faults is also different between the fold-thrust and foreland belts. In the fold-thrust belt the faults are initiated as horizontal or subhorizontal decollements, ramp upward at an angle generally less than 45 degrees and flatten again along planes of weakness (Royse et al., 1975; Boyer and Elliott, 1982). Foreland faults have a variety of geometries, ranging from thrusts dipping about 30 degrees to near-vertical faults (Prucha et al., 1965; Gries, 1983). The magnitude of shortening in the fold-thrust belt is measured in tens to hundreds of kilometers, whereas in the foreland vertical throw is generally greater than the amount of horizontal shortening. Finally, because the fold-thrust belt spread cratonward through time, detritus deposited adjacent to active thrust sheets were subsequently involved in the deformation associated with movement of the next thrust sheet. The foreland, on the other hand, consists of discrete blocks separated by largely undeformed basins, and only basin-margin strata is involved in the deformation.

Using the criteria outlined above, Laramide deformation in the Florida Mountains and southern Cooke's Range most closely resembles the style of the Rocky Mountain foreland. The south Florida Mountains fault clearly involves crystalline basement and is very steep. Furthermore, provenance of the Lobo Formation in both the intra-uplift and northern basins indicates that crystalline basement was exposed in the core of the uplifted blocks. The magnitude of shortening in the vicinity of the Florida Mountains and elsewhere in southwestern New Mexico was small. Paleozoic isopach and facies patterns are not offset to any great degree, as would be expected in an area of hundreds of kilometers of shortening (Kottlowski, 1965; Greenwood et al., 1977; Hayes, 1975; Mack et al., 1986; Clemons, in press). The El Paso Formation shows no deviations from being a shallow-marine platform deposit from Willcox, Arizona eastward to Van Horn, Texas, and northeastward to Truth or Consequences, New Mexico (Clemons, 1987). Recent detailed mapping in the Florida and Animas Mountains and Klondike Hills, combined with facies analyses of late Paleozoic strata and subsurface data, indicate no deep basin facies (present southwest of the Big Hatchet Mountains) have been moved northeastward onto the late Paleozoic shelf area between Animas and Deming (Armstrong, 1970; Thompson and Jacka, 1981; Brown, 1982; Clemons, in press; Donnan, 1987; Mack and James, 1986; Rupert, 1986; Wilson, 1986). Finally, Laramide deformation of the Lobo Formation is restricted to rocks deposited directly adjacent to boundary faults and basin-center facies are undeformed.

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