Uplift, erosion, and burial of Laramide fault blocks, Salado Mountains, Sierra County, New Mexico

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Introduction

In recent years Laramide deformation in south-central New Mexico has been compared to that of the central Rockies of Wyoming (Seager and Mack, 1986; Seager and others, 1986). The structural style in both areas is distinguished by basement-cored block uplifts separated by broad basins filled with synorogenic to post-orogenic sedimentary rocks. Thrust or reverse faults border uplift-basin margins, at least on one side, and these, as well as associated tight, overturned folds, indicate substantial crustal shortening.

In south-central New Mexico, uplifts and basins trend north-northwest to nearly east-west, highly oblique to the northerly trend of late Tertiary fault blocks of the Rio Grande rift. Thus, the Laramide uplifts are truncated and segmented by the younger faults so that fragments of the Laramide structures are often revealed in cross section in the modern ranges. Such fragments, exposed near the Rio Grande from the Caballo Mountains south to the East Potrillo Mountains, constrain the location, trend, and geometry of the Laramide Rio Grande uplift (Fig. 1) and its two complementary basins, the Love Ranch and Potrillo Basins (Seager and others, 1986).

FIGURE 1—Location map. Shaded area shows extent of Laramide Rio Grande uplift as interpreted by Seager et al. (1986).
15 km nearly due west of Truth or Consequences (Fig. 1; Lamarre, 1974; Mayer, 1987). In this area not only is the Laramide fault-block structure revealed, but also the manner in which the fault blocks were eroded and eventually buried by younger volcanic rocks.

**General features and stratigraphy of the Salado Mountains**

The Salado Mountains are a relatively small (approximately 20 km²) group of hills and peaks located near the center of the easternmost, outlying fault block of the Black Range. To the north, the fault block is known as Sierra Cuchillo, to the south it goes by the name Animas Mountains. Bordering on the west by a late Tertiary normal fault, downthrown to the west, the whole fault block is tilted eastward (Fig. 2). In the Salado Mountains the easterly dip ranges from approximately 15 to 25 degrees, and strata dip eastward beneath gravels of the Palomas Basin.

Rocks ranging in age from Precambrian to Quaternary crop out in the Salado Mountains (Fig. 3). Precambrian rocks include granite, muscovite phyllite and schist, and metadiorite, all exposed in the core of a Laramide fault-block uplift. Paleozoic strata nonconformably overlie the Precambrian and range in age from Cambrian-Ordovician to Permian. Largely marine limestone, dolomite, shale, and sandstone, these rocks form the highest hills and peaks in the mountain group. Because of erosion during or following the Laramide or faulting during the late Tertiary, parts of the El Paso, Montoya, and Abo sections either are not exposed or are missing altogether. In spite of this, a thickness of approximately 600 m of Paleozoic rock crops out (Mayer, 1987).

Middle Tertiary volcanic and clastic rocks overlie Paleozoic strata, the contact being an angular unconformity of modest (10 to 15 degrees) discordance. Middle Tertiary strata have an uneven thickness because lower parts of the section are inset against or onlap Laramide topography whereas somewhat younger rocks overlap completely and bury the older terrane. Among the oldest of the Tertiary rocks are post-orogenic boulder conglomerate and breccia beds, only a few meters thick, derived from an adjacent Laramide uplift. Clasts are as much as several meters in diameter and include Paleozoic strata as old as the Bliss Formation. Conglomerates probably are correlative with the Love Ranch Formation of the Caballo–San Andres Mountains area (Kottlowski et al., 1956). The Love Ranch strata grade upward into or are interbedded with intermediate-composition flows and volcaniclastic strata of the Rubio Peak Formation (Palm Park, Spears, or Datil Group equivalent; Elston 1957; Kelley and Silver, 1952; Seager and Hawley, 1973; Cather et al., 1987). Much of the formation is laharic in origin. As much as 1,075 m thick, the formation thins dramatically both because its lower beds pinch out by onlap onto Lar-

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**FIGURE 2—Generalized geologic map of the Salado Mountains, modified after Mayer (1987).** pC, Precambrian rocks; Pl, lower Paleozoic rocks; DM, Devonian and Mississippian rocks; P, Pennsylvanian rocks; Pa, Permian Abo Formation; Tlr, Love Ranch Formation; Trp, Rubio Peak Formation; Ttu, unnamed crystal ash-flow tuff; Tba, basaltic andesite flows; Ts, lower Santa Fe Group; Tb, basalt flows; QTp, Palomas Formation; Tai, biotite andesite dike; Tiu, igneous intrusions, undifferentiated.
are truncated by an unconformity. Radioam ide to earliest Oligocene in age (e.g. Kottlovsk et al., 1969; Marvin and Cole, 1978; Clemens, 1982; Loring and Loring, 1980). Unconformably above the Rubio Peak Formation, two ash-flow tuffs of probable middle Oligocene age crop out along the eastern and southern flanks of the mountains. The lower tuff, 100 to 200 m thick, has not been correlated with other tuffs of the region. The upper tuff, 30 to 60 m thick, is crystal rich and also has not been correlated with other tuffs. Scattered remnants of basaltic andesite flows, inferred to be correlative with Bear Springs basalt (Elston, 1957) or basaltic andesite of Poverty Creek (Elston et al., 1973), unconformably overlie the tuffs or Rubio Peak Formation. Recent K–Ar dating indicates these units are approximately 28 Ma old (Seager et al., 1984).

Unconformably overlying various parts of the middle Tertiary volcanic section is a sequence of "early rift" fanglomerate, sandstone, and siltstone assigned to the lower Santa Fe Group. A thousand meters or more thick in outcrops along Salado Creek, the formation was derived primarily from middle Tertiary volcanic rocks. It may be correlative with all or part of the Miocene Hayner Ranch and Rincon Valley Formations of the Caballo Mountains–Hatch Valley area (Seager and Hawley, 1973) and with the Popotosa Formation of the Socorro area (Denny, 1940; Bruning, 1973; Chapin and Seager, 1975). The unit dips eastward 15 to 25 degrees and was clearly rotated along with older strata as the Salado Mountains block was uplifted and tilted eastward in late Tertiary time.

Essentially undeformed basalt flows and piedmont-slope gravels unconformably overlie older rock units. The basalt issued from vents to the west of the Salado Mountains, then flowed eastward down ancestral drainage ways such as Salado Creek. Locally, the flows may be offset a few meters by movement on range-boundary faults. The flows now cap geomorphically high-level mesas or ridge tops. Judging from dated flows in similar geomorphic positions near Hillsboro, the flows may be approximately 4 to 4.5 Ma (Seager et al., 1984). Piedmont-slope gravels assigned to the Palomas Formation (Lozinski and Hawley, 1986) of latest Pliocene and Pleistocene age bury the basalt flows and overlap older rock units. Late Quaternary and Holocene alluvium in arroyos or shallow drainageways are the youngest deposits in the area.

**Laramide structure**

Erosion of the late Tertiary Salado Mountains fault block has revealed a fragment of an older fault-block uplift of probable Laramide age. Because the Laramide uplift and its boundary fault trend nearly east–west, they are truncated on the west by the north-trending boundary fault of the Salado Moun-

tains and buried on the east by post-Laramide volcanic and sedimentary rocks. In between, the Laramide geology is well exposed, particularly in the Chavez Canyon area (Fig. 2).

The central Laramide structure is the Chavez Canyon fault (Fig. 2), movement on which raised a Laramide fault block of modest relief. The fault trends N85°W and is upthrown on the south side. Precambrian and lowest Paleozoic rocks in the uplifted block are juxtaposed against Ordovician to Pennsylvanian strata in the down-faulted block to the north. Stratigraphic separation is as much as 400 m. Unfortunately, the dip of the fault is not known precisely because the fault is intruded throughout its length by a 50-m-thick biotite andesite dike. The trace of the

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**FIGURE 3—Columnar section of sedimentary and volcanic rocks exposed in Salado Mountains.**
that the Laramide Basin is hidden beneath Range or Sierra Cuchillo so it seems likely orogenic deposits are known in the Black cumulations of Laramide synorogenic or post-
and presumably that basin contains the de-
relative to some unknown adjacent basin,
footwall. Both blocks were structurally high
and all but 700 m were removed from the
area. Almost the tritus derived from the uplifts. No thick ac-
the hanging wall of the Chavez Canyon fault
during or following Laramide deformation,
the entire Phanerozoic section was eroded from
served in the Sierra Cuchillo (Jahns, 1955)
2,000 m thick covered the Salado Mountains
leozoic and Mesozoic strata approximately
missing in the Salado Mountains but are pre-
the Chavez Canyon fault blocks (Fig. 4). Pres-
eration of Cretaceous rocks in the Palomas Basin in the Summit 1 Mims and Fortland
1 Brister wells supports this (Foster, 1978).
by middle Tertiary time Laramide fault
blocks in the Salado Mountains were buried
by volcanic rocks. If one views the geologic
map (Fig. 2) from the west looking eastward
down dip, the map takes on the aspects of a
cross section, and the manner in which the
uplift was buried becomes clear.
Figure 5, a diagrammatic cross section de-
nered from the "down plunge" view of the
geologic map, shows the important relations-
ships. A pediment cut on the downthrown
block of the Chavez Canyon fault is covered
discontinuously by bouldery debris of the
Love Ranch Formation derived from the up-
thrown block. These beds also interfinger with
basal beds of the Rubio Peak Formation. An-
desite lava flows of the Rubio Peak fill some
of the deepest drainageways incised into
parts of the Palomas Basin. Perhaps the Lar-
amide Love Ranch Basin, well exposed in
western parts of the Jornada del Muerto, ex-
tends northwesward beneath the Palomas Basin and contains erosional debris from the
Chavez Canyon fault blocks (Fig. 4). Pres-
eration of Cretaceous rocks in the Palomas Basin in the Summit 1 Mims and Fortland
1 Brister wells supports this (Foster, 1978).
Age of Laramide deformation
The age of Laramide deformation in the
Salado Mountains is poorly constrained. The
only direct evidence we have for the age of
the Chavez Canyon fault is a K-Ar date from the andesite dike that intrudes the fault. La-
amre (1974) dated biotite from this dike at 43.7 ±1.7 Ma. The fault is therefore older.
Regional relationships suggest Laramide deformation in the Truth or Consequences region may have occurred in two pulses (Chapin and Cather, 1981): an earlier one in latest Cretaceous to Paleocene time related to deposition of the McKae Formation (Hunter, 1986), and a later one in early to middle Eocene time related to emplacement of the Love Ranch Formation (Seager, 1983; Seager and Mack, 1986). Little is known about the earlier phase. The Salado Mountains de-
formation may be a product of the younger event because Love Ranch-type clastic strata
derived from the hanging wall of the Chavez Canyon fault are present in the basal parts of the Rubio Peak Formation.
Figure 4 illustrates that the Laramide fault
blocks in the Salado Mountains may be in-
Erosion and burial of the Laramide uplifts
Before Laramide deformation began, Pa-
leozoic and Mesozoic strata approximately
2,000 m thick covered the Salado Mountains
area (Kottlowski, 1963). This approximation
includes estimates of the thickness of Per-
ian and Upper Cretaceous rocks that are
missing in the Salado Mountains but are pre-
served in the Sierra Cuchillo (Jahns, 1955)
and Truth or Consequences area. Almost the
entire Phanerozoic section was eroded from
the hanging wall of the Chavez Canyon fault
during or following Laramide deformation,
and all but 700 m were removed from the
footwall. Both blocks were structurally high
relative to some unknown adjacent basin,
and presumably that basin contains the
dributus derived from the uplifts. No thick ac-
cumulations of Laramide synorogenic or post-
orogenic deposits are known in the Black
Range or Sierra Cuchillo so it seems likely
that the Laramide Basin is hidden beneath
lowest parts of the paleopiedmont slope.
Younger Rubio Peak laharc strata progres-
sively onlap the piedmont slope, eventually
burying the dike in the Chavez Canyon fault.
Perhaps the Rubio Peak Formation also bur-
ded the hanging-wall block of the Chavez
Canyon fault; this is not entirely clear be-
cause erosion locally removed part of the up-
per beds of the Rubio Peak Formation before
emplacement of the overlying tufts. At any
rate, the Rubio Peak Formation thins by dep-
oxination as it onlaps the Laramide fault blocks and thickens to the north. Clearly, the Rubio
Peak strata leveled the former topography.
Succeeding sheets of ash-flow tuff over-
lapped the eroded Rubio Peak strata as well
as the structurally highest parts of the Lar-
amide uplift south of Chavez Canyon fault;
finally the ash-flow tuffs buried the uplift
completely. Emplacement of basaltic andes-
ite flows and deposition of Santa Fe fan-
glomerate further concealed the Laramide
fault block.
Regional relationships
FIGURE 4—Interpreted extension of Laramide Rio Grande uplift and Love Ranch Basin into Black Range
area. Dotted areas are parts of Black Range where pre-Laramide rocks are exposed. Symbols T/pE, T/ PI, T/PP, T/Pa, T/Psa, T/K refer to areas where Tertiary volcanic or clastic rocks overlie Precambrian,
lower Paleozoic, Pennsylvanian, Abo, San Andres Limestone, or Cretaceous rocks respectively.
terpreted as a westward extension of northern parts of the Rio Grande uplift of the Caballo Mountains area. The easterly trend of the Chavez Canyon fault blocks is nearly parallel to westernmost exposures of the Rio Grande uplift-margin structures in the central Caballo Mountains. Also, the northward downstepping of faults is consistent in both areas.

The Rio Grande uplift of the Caballo Mountains—southern Rio Grande area is a huge structure, consisting of at least two major blocks and several smaller ones (Seager et al., 1986). Consequently, it is unlikely that the relatively small fault blocks of the Salado Mountains represent the full extent of the Rio Grande uplift in the Black Range area. They probably are intra-uplift blocks or elements of a much broader uplift that probably extends southward to Lake Valley or beyond as well as westward and northward. Parts of this inferred broad uplift were raised sufficiently high so that erosion cut into broad areas of Precambrian or lower Paleozoic rocks prior to late Eocene time (Fig. 4). For example, in and adjacent to North Percha Creek in the east-central Black Range, the Rubio Peak Formation thins onto Laramide uplands, and Precambrian granite is overlapped by sheets of younger ash-flow tuff (Ericksen et al., 1970; Seager et al., 1982). These are the same onlap and overlap relationships displayed so strikingly in the Salado Mountains. Only locally are rocks as young as Permian preserved beneath Tertiary volcanics in the central and southern Black Range area; these must represent local intra-uplift sags or synclines in the broader uplift.

Conclusions

The Laramide uplift in the Salado Mountains is probably only a small element of a much broader uplift of early Tertiary age—the Rio Grande uplift—that encompassed much of the central and southern Black Range as well as broad areas to the east and south. The Salado Mountains structure trends N85°W, in approximate conformity with Laramide trends in other parts of the Rio Grande uplift but at high angles to younger Rio Grande rift faults. Erosion of 1500 to nearly 2,000 m of Paleozoic and Mesozoic strata from the Salado Mountains area is an index of the magnitude of Laramide uplift in the region. Except for very thin post-orogenic pediment veneers, sedimentary deposits resulting from this erosion are missing, even on the structurally lowest blocks. They must have been transported across the uplift into adjacent basins that now lie hidden beneath the late Tertiary Palomas Basin. By late Eocene time considerable topographic relief still existed across Laramide fault blocks. Subsequent deposition of upper Eocene to lower Oligocene lavas and volcaniclastic rocks leveled the landscape, and lower Oligocene ash-flow tuffs finally buried the highest, most deeply eroded fault blocks. Such onlap and overlap relationships of middle Tertiary volcanics onto eroded Laramide uplifts can be seen in many parts of southern New Mexico, but are perhaps nowhere more clearly revealed than in the Salado Mountains.

Acknowledgments—Mapping in the Salado Mountains was done by Seager in the early 1970s and in 1987. Mayer mapped the area as part of his M.S. geology degree in early 1970s and in 1987. Mayer mapped the area as part of his M.S. geology degree in 1986 and 1987. We appreciate the helpful reviews of Steve Cather, Richard Harrison, Tim Lawton, and Greg Mack.

References


Cather, S. M., McIntosh, W. C., and Chapin, C. E., 1987, Stratigraphy, age, and rates of deposition of the Datil Group (Upper Eocene–Lower Oligocene), west-central New Mexico: New Mexico Geology, v. 9, pp. 50–54.


(continued on page 60)
(continued from page 53)
Kelley, V. C., and Silver, C., 1952, Geology of the Caballo Mountains with special reference to regional stratigraphy and structure and to mineral resources, including oil and gas: University of New Mexico Publications in Geology, no. 4, 286 pp.

Summary of charges for natural resources other than oil and gas on New Mexico State Lands as of January 1, 1988
compiled by Louis B. Martinez, State Land Office, Mineral Division (505/827-5776), and James M. Barker, New Mexico Bureau of Mines and Mineral Resources (505/835-5114)

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Data source: State Land Office, Mineral Division. *For information, contact the State Land Office, Mineral Division.

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