Klondike Basin--Late Laramide depocenter in southern New Mexico

Timothy F. Lawton and Russel E. Clemons

New Mexico Geology, v. 14, n. 1 pp. 1-7, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
https://doi.org/10.58799/NMG-v14n1.1

This page is intentionally left blank to maintain order of facing pages.

New Mexico GEOLOGY
• Science and Service
ISSN 0196-948X
Volume 14, No. 1, February 1992

Klondike Basin—late Laramide depocenter in southern New Mexico

by *Timothy F. Lawton* and *Russell E. Clemons*,
Department of Earth Sciences, New Mexico State University, Las Cruces, NM 88003

Abstract

The Klondike Basin defined in this paper occurs mostly in the subsurface of southwestern New Mexico, north of the Cedar Mountain Range and southwest of Deming. The basin is asymmetric, thickening from a northern zero edge in the vicinity of Interstate 10 to a maximum preserved thickness of 2,750 ft (840 m) of sedimentary strata about 3 mi (5 km) north of the southern basin margin. The southern basin margin is a reverse fault or fault complex that bounds the Laramide Luna uplift, also defined here. The uplift consists of Paleozoic strata overlain unconformably by mid-Tertiary ash-flow tuffs and andesitic volcanics.

The principal sedimentary unit of the Klondike Basin is the Lobo Formation. It was deposited in alluvial-fan, fluvial, and playa environments adjacent to the Luna uplift. Conglomerates in the lower part of the section were derived from nearby sedimentary strata of the uplift; volcanic arenites in the middle and upper part of the section were derived from older volcanic rocks, including the Hidalgo Formation, lying to the west and northwest, and possibly to the north as well.

The age of the Lobo Formation and development of the Klondike Basin are bracketed as early to middle Eocene. The Hidalgo Formation, which occurs as clasts in the Lobo, has an upper fission-track age of 54.9 ± 2.7 Ma (Marvin et al., 1978). The overlying Rubio Peak Formation in the Victorio Mountains is 41.7 Ma (Thorman and Drewes, 1980). The Klondike Basin is thus a member of a group of late Laramide basins developed in and adjacent to the foreland in Paleogene time.

Introduction

In southwestern New Mexico and southeastern Arizona, the Laramide orogeny created a broad belt of northwest-trending faults and folds during the approximate time span of 75–55 Ma (Davis, 1979; Drewes, 1988). In contrast with Laramide deformation of the Rocky Mountain region, extensive volcanism accompanied shortening in Arizona and New Mexico. This volcanism has been interpreted as subduction related (Coney and Reynolds, 1977; Keith, 1979). The deformation itself has been attributed to underthrusting of the Farallon plate beneath North America (Seager and Mack, 1986).

Sedimentary basins formed in association with Laramide deformation. Laram- ☞

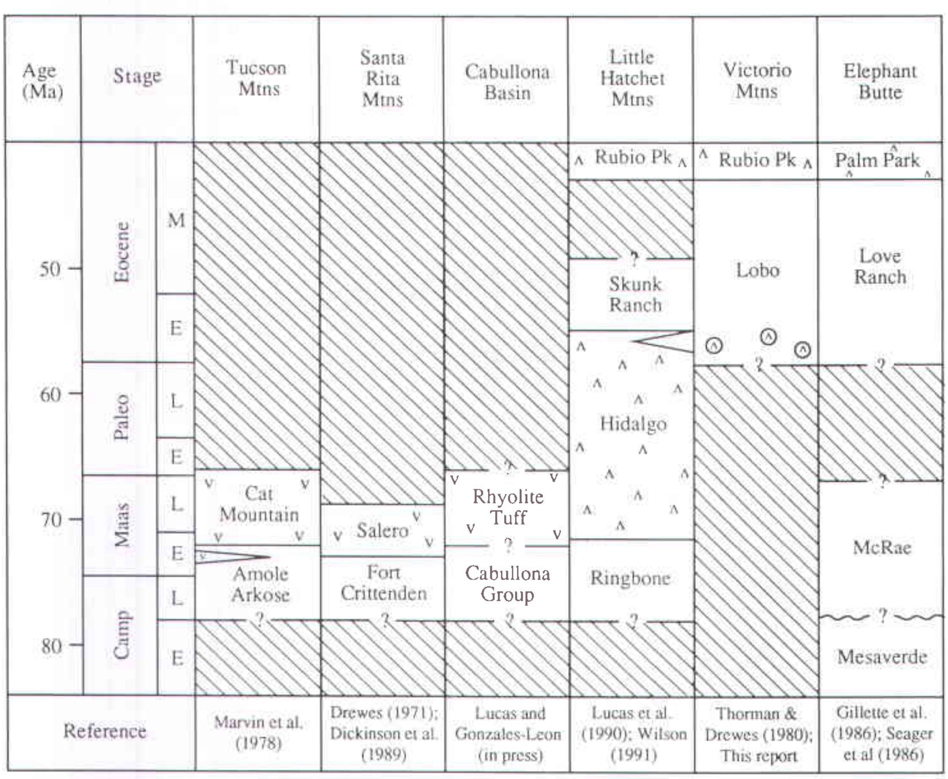


FIGURE 1—Correlation chart of Laramide sedimentary strata and volcanic units of southeastern Arizona, southwestern New Mexico, and south-central New Mexico. Volcanic symbols: v, silicic volcanics; inverted v, intermediate volcanics. Age of Amole Arkose in Tucson Mountains interpreted from interfingering relations with Confidence Peak Tuff of Late Cretaceous age (P. J. Lipman, personal communication 1990). Inverted v symbol in Lobo denotes presence of andesitic clasts in Lobo conglomerates. Paleogene time scale from Berggren et al. (1985).

Also in this issue

ide sedimentary units include an assemblage of strata that range in age from Late Cretaceous to middle(?) Eocene (Fig. 1), although ages of the Paleogene units are as yet poorly constrained. Improved interpretation of the timing and style of Laramide deformation hinges on our understanding of the ages and distribution of these syntectonic units. The objective of this report is to describe the evidence for a newly discovered Laramide basin, here named the Klondike Basin, in southwestern New Mexico and to discuss its significance. The Klondike Basin takes its name from a small range known as the Klondike Hills immediately north of the Cedar Mountain Range (Pearce, 1965).

Stratigraphic correlations of sedimentary formations deposited as a result of Laramide deformation suggest that at least two generations of Laramide basins exist (Fig. 1). The older generation, ranging in age from Campanian through late Maastrichtian, encompasses the Fort Crittenden Formation in Arizona, the Cabullona Group in Sonora, and the Ringbone and McRae Formations in New Mexico (Dickinson et al., 1989; Basabilvazo, 1991; Gillette et al., 1986). Ages of the formations are understood largely from interpretations of the biostratigraphic significance of dinosaur fossils (Miller, 1964; Lucas et al., 1990; Lucas and Gonzalez-Leon, in press). The younger generation of basins is probably late Paleocene to Eocene and is represented by the Love Ranch, Lobo, and Skunk Ranch Formations (Seager and Mack, 1986; Seager et al., 1986; Wilson et al., 1989; Wilson, 1991). Representative late-Laramide basins include the Potrillo and Love Ranch Basins (Seager and Mack, 1986). The late Laramide basins of the Paleogene developed on the North American craton, whereas the early Laramide basins of the Cretaceous developed within the region of the older Bisbee Basin and Chihuahua trough, which formed by crustal extension in Early Cretaceous time (Dickinson, 1981; Bilodeau, 1982; Mack et al., 1986; Dickinson et al., 1989).

Methods

The Klondike Basin was defined largely through subsurface analysis (Clemons and Lawton, 1991). Cuttings from three wells (Fig. 2) were prepared as thin sections and examined petrographically. Gamma-ray and sonic logs of the wells were correlated, and formation tops picked from cuttings were depth adjusted to match lithologic changes indicated by the well logs. Surface sections of Paleozoic, Mesozoic, and Tertiary strata were examined in the Victorio Mountains, Cedar Mountain Range, Klondike Hills, and West Lime Hills in order to compare lithologies seen in cuttings with the variability of interbedded lithic types observed in outcrops. The thicknesses of units depicted in Fig. 3 were reconstructed using dips indicated by dipmeter logs for the Saltys and Bisbee Hills wells. Fig. 3 was constructed by projecting the sections on to a line of azimuth 20° located midway between the Saltys and Bisbee Hills wells.

Geologic setting

In the Cedar Mountain Range south of the Bisbee Hills well, lower Paleozoic strata are overlain by conglomerate with clasts derived dominantly from Lower Cretaceous strata. The conglomerate and Paleozoic strata are overlain by mid-Tertiary ash-flow tuffs (Bromfield and Wrucke, 1961); no Lower Cretaceous rocks are exposed in the range. Southeastward, along the general trend of the northern flank of the Cedar Mountain Range, the West Lime Hills contain a series of northeast-vergent reverse faults, the southwesternmost of which emplaces Permian carbonates (Thompson, 1982) above conglomerate composed of Paleozoic carbonate clasts.

FIGURE 3—Correlation of stratigraphy of the Victorio Mountains and subsurface units encountered in the Saltys, Cockrell, and Bisbee Hills wells, shown as projected onto a section trending N20°E through the Victorio Mountains. See Fig. 2 for well locations. Explanation: **Ob**, Bliss Formation; **Oe**, El Paso Formation; **Om**, Montoya Group; **Sf**, Fusselman Formation; **Dp**, Percha Shale; **Mk**, Keating Formation; **Mh**, Hachita Formation; **Mp**, Paradise Formation; **Ph**, Horquilla Formation; **Pe**, Earp Formation; **Kl**, undifferentiated Lower Cretaceous; **Kh**, Hell-to-Finish Formation; **Ku**, U-Bar Formation; **Km**, Mojado Formation; **Tl**, Lobo Formation; **Tr**, Rubio Peak Formation; **Tv**, mid-Tertiary tuffs.

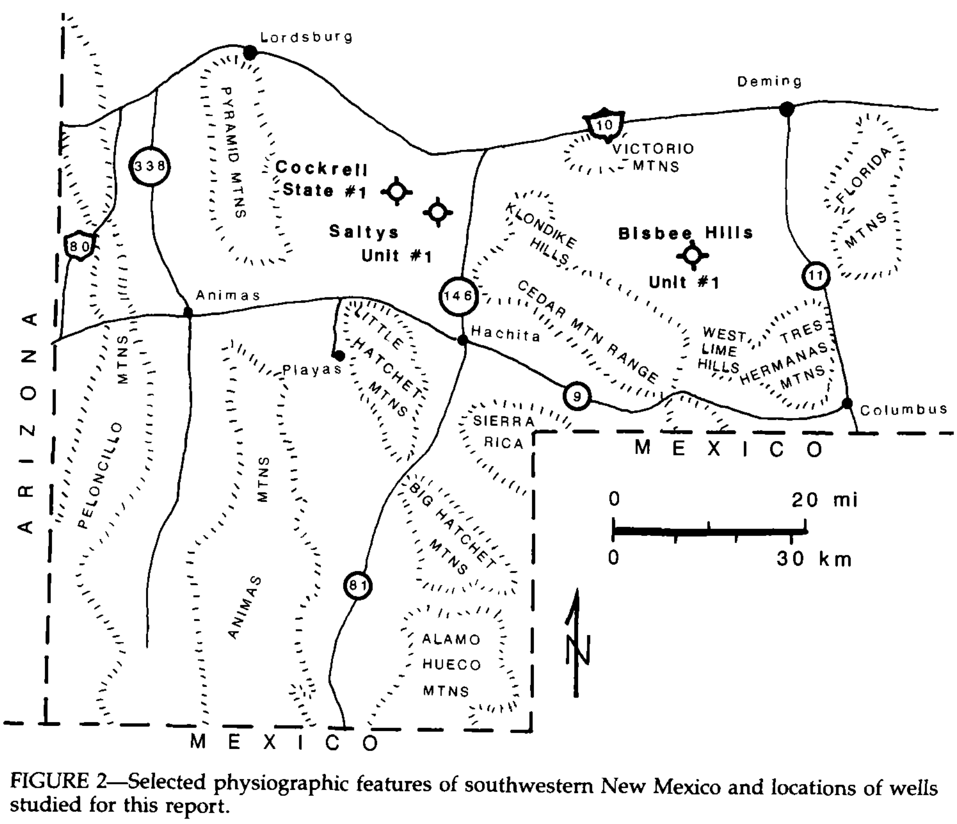


FIGURE 2—Selected physiographic features of southwestern New Mexico and locations of wells studied for this report.

New Mexico GEOLOGY
• Science and Service
ISSN 0196-948X
Volume 14, No. 1, February 1992

Editor: Carol A. Hjellming

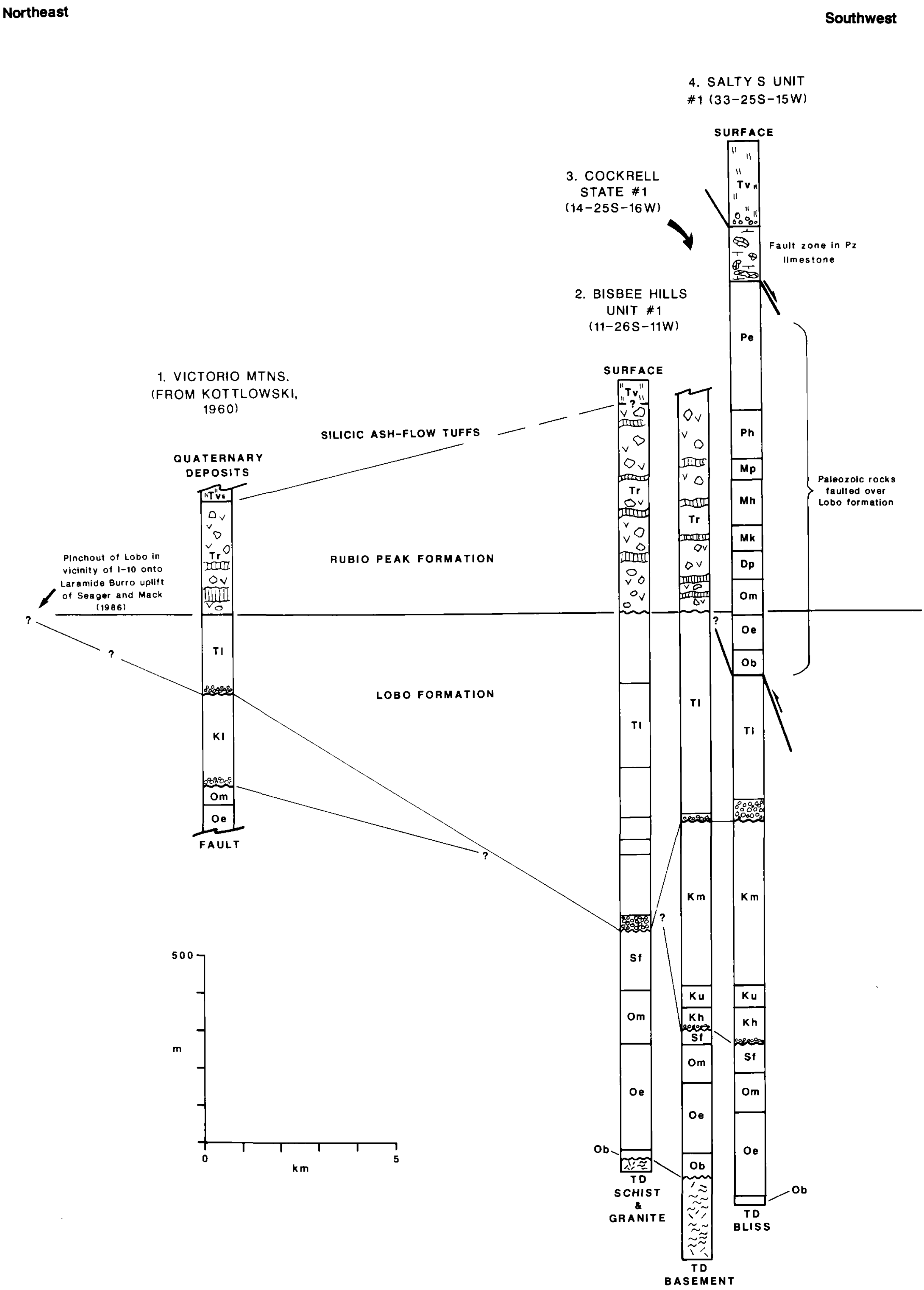
Published quarterly by
New Mexico Bureau of Mines and Mineral Resources
a division of New Mexico Institute of Mining & Technology

Subscriptions: Issued quarterly, February, May, August, November; subscription price $6.00/calendar year.

Editorial matter: Articles submitted for publication should be in the editor's hands a minimum of five (5) months before date of publication (February, May, August, or November) and should be no longer than 20 typewritten, double-spaced pages. All scientific papers will be reviewed by at least two people in the appropriate field of study. Address inquiries to Carol A. Hjellming, Editor of *New Mexico Geology*, New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801-4796.

Circulation: 1,600

Printer: University of New Mexico Printing Services


Northeast
Southwest
4. SALTY S UNIT #1 (33-25S-15W)
SURFACE
3. COCKRELL STATE #1 (14-25S-16W)
Fault zone in Pz limestone
2. BISBEE HILLS UNIT #1 (11-26S-11W)
1. VICTORIO MTNS. (FROM KOTTLOWSKI, 1960)
SILICIC ASH-FLOW TUFFS
QUATERNARY DEPOSITS
Paleozoic rocks faulted over Lobo formation
Pinchout of Lobo in vicinity of I-10 onto Laramide Burro uplift of Seager and Mack (1986)
RUBIO PEAK FORMATION
LOBO FORMATION
FAULT
Tv
Tr
Tl
Kl
Km
Ku
Kh
Sf
Om
Oe
Ob
Pe
Ph
Mp
Mh
Mk
Dp
500
m
0
5
km
TD SCHIST & GRANITE
TD BASEMENT
TD BLISS

The conglomerate may be Hell-to-Finish Formation (Lower Cretaceous) or Lobo. The conglomerate is faulted against metamorphosed and overturned Ordovician through Mississippian strata, which are in turn thrust over the Hell-to-Finish Formation. This system of faults trends northwestward toward the Cedar Mountain Range and illustrates the structural complexity created by Laramide deformation in the area.

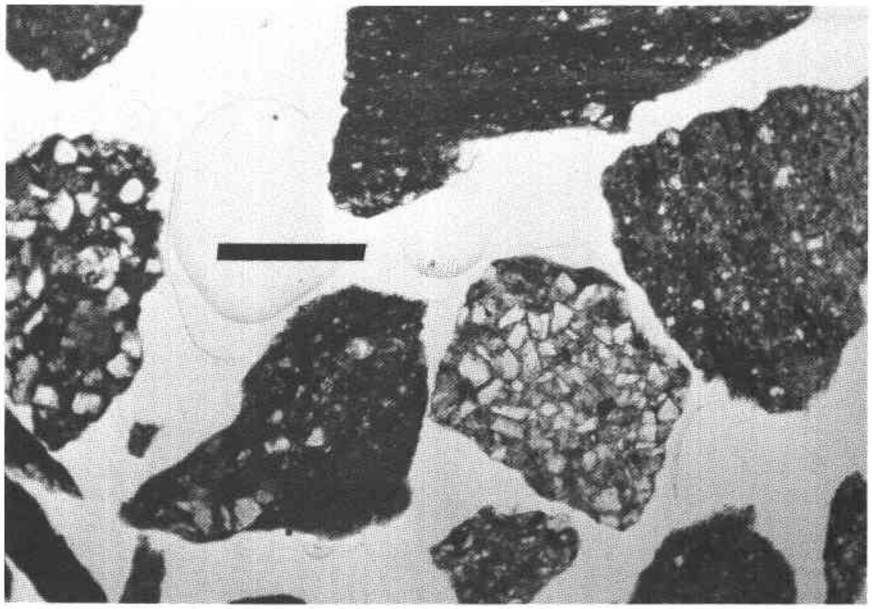
In the Victorio Mountains, a thin (790 ft; 240 m) Lower Cretaceous section (Kottlowski, 1960) overlies Ordovician and Silurian strata. The Lower Cretaceous section is overlain unconformably by 690 ft (210 m) of reddish-brown conglomerate, sandstone, and siltstone (Kottlowski, 1960) that we consider to be Lobo Formation. The Lobo in the Victorio Mountains is overlain concordantly by hornblende-andesite flows and breccias of the Rubio Peak Formation. Ages on the Rubio Peak Formation range from 44.7 to 32.6 Ma in the Cooke's Range to the north (Loring and Loring, 1980; Clemons, 1982). A zircon fission-track age of 41.7 ± 2.0 Ma was reported from a flow breccia in the Victorio Mountains (Thorman and Drewes, 1980).

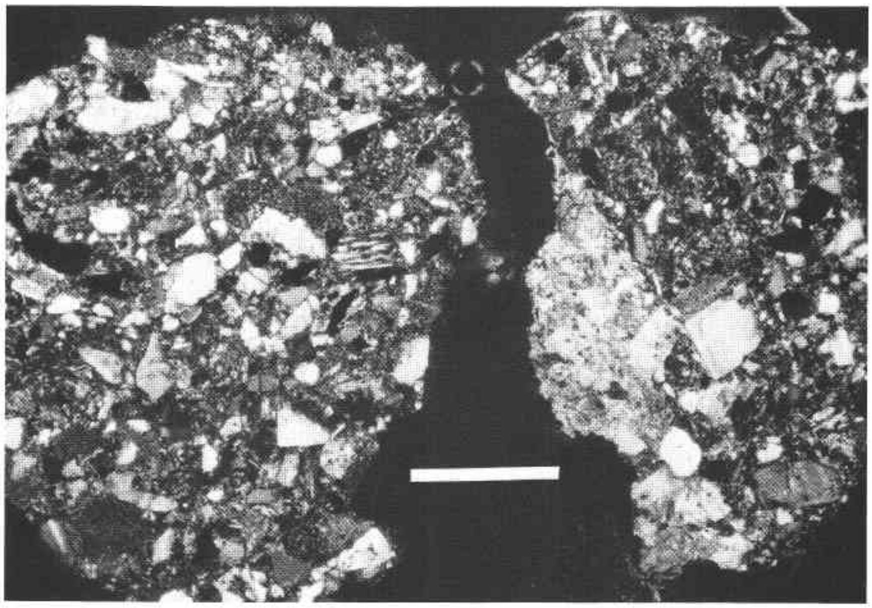
Subsurface relations

Three wells southwest of Deming penetrated thick sections of Lobo. The thickness of the unit is 2,750 ft (840 m) in the Bisbee Hills Unit #1, 1,800 ft (550 m) in the Cockrell State #1, and 1,050 ft (320 m) in the Saltys Unit #1 (thicknesses of intrusive rocks have been removed from the sections). In the Saltys well, the Lobo is truncated beneath a reverse fault with Ordovician through Permian strata in the hanging wall (Fig. 3).

In the Saltys and Cockrell wells the Lobo rests on a sequence of glauconitic marine sandstones and shales that we interpret as the upper part of the Mojado Formation (Albian–Cenomanian?). These marine beds at the top of the Mojado overlie a thick inverval of nonmarine strata consisting of fine-grained sandstone, siliceous siltstone, and silty mudstone. Palynomorphs from this nonmarine interval in the Cockrell well include Cicatricosisporites spp. and Quadripollis krempii, which are both long-ranging Cretaceous forms (S. N. Nelson, written communication June 14, 1990).

The basal contact of the Lobo is somewhat anomalous in the Bisbee Hills well. Although the unit appears to contain a basal conglomeratic interval, the Lower Cretaceous section is absent and the Lobo directly overlies Silurian Fusselman Dolomite (Clemons and Lawton, 1991). In the other two wells, Lower Cretaceous strata overlie the Fusselman. Two possible interpretations are: 1) the Lower Cretaceous section was eroded prior to Lobo deposition in the Bisbee Hills well; 2) the Lower Cretaceous section is absent in the Bisbee Hills well as a result of faulting. Presently





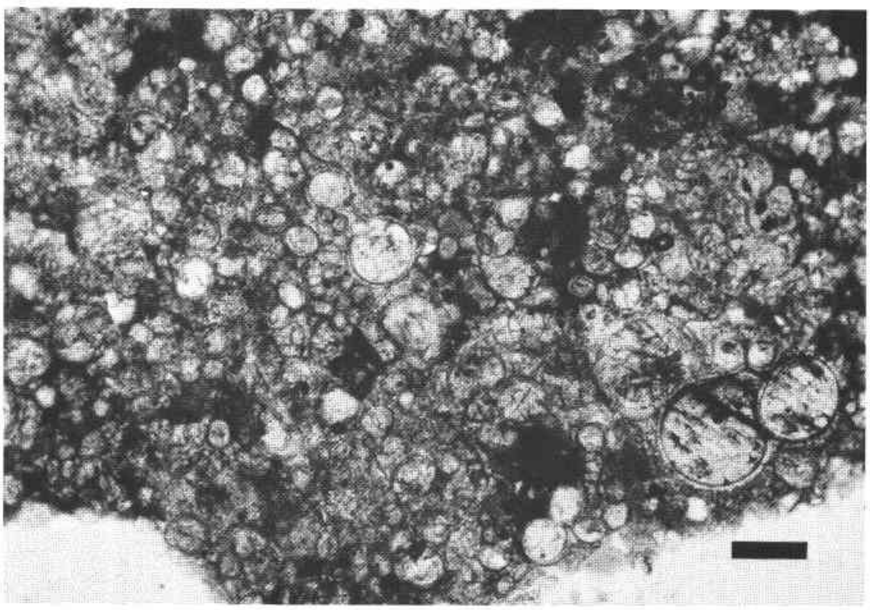


FIGURE 4—Silty mudstone, muddy siltstone, and calcareous fine-grained sandstone with very angular to subangular quartz and plagioclase. Lobo Formation, Saltys well, 5,500 ft. Plane-polarized light; bar = 0.5 mm.

FIGURE 5—Poorly sorted, fine-grained, calcareous volcanic arenite with angular to subangular quartz, plagioclase, biotite, magnetite, and andesite fragments. Lobo Formation, Bisbee Hills well, 3,750 ft. Crossed nicols; bar = 0.5 mm.

FIGURE 6—Silty calcareous mudstone with spar-filled globigerinids. Conglomerate in lower part of Lobo Formation, Saltys well, 5,830 ft. Plane polarized light; bar = 0.1 mm.

available data do not permit us to reject either of these possibilities; however, the Lobo section is thickest in the Bisbee Hills, indicating that subsidence was greater there than at the other studied localities. This observation favors omission by faulting because it obviates the need for major post-Early Cretaceous uplift and erosion followed by major Paleogene subsidence.

The Lobo Formation in the Bisbee Hills well consists of interbedded reddish-brown silty mudstone, siltstone, and very fine to medium-grained calcareous sandstone (Fig. 4; Clemons and Lawton, 1991). The basal 140 ft (43 m) is conglomerate containing clasts of silty shale and mudstone, calcareous fine-grained sandstone, silty limestone, dolostone, chert, and lower Paleozoic limestone. Angular to subangular quartz grains, carbonate and volcanic rock fragments, chert, plagioclase, potassium feldspar, and traces of biotite are present in the sandstone beds. Sandstones of the middle and upper parts of the Lobo section are dominantly volcanic arenites (Fig. 5).

In the Cockrell well, the lower 40 ft (12 m) of the Lobo Formation is conglomerate with clasts that contain globigerinid-like forams (Fig. 6). Other lithologies present as clasts are shale, mudstone, and siliceous medium-grained sandstone with quartz overgrowths. Above the conglomerate are 740 ft (226 m) of interbedded reddish-brown mudstone, shale, calcareous fine- to medium-grained sandstone, and siliceous medium-grained sandstone. Like the sandstone of the lower part of the Lobo in the Bisbee Hills well, sandstone in the Cockrell well contains angular to subrounded grains of quartz, chert, plagioclase, minor potassium feldspar, biotite, and carbonate rock fragments. The upper 1,110 ft (339 m) of the formation in the Cockrell well is fine grained and consists of interbedded reddish-brown mudstone, shale, calcareous siltstone, and claystone. The Lobo in the Saltys well is very similar to that in the Cockrell well, but it contains more sandstone. The lower 180 ft (55m) of Lobo in the Saltys well is probably conglomerate with mixed lithologies that include globigerinid-like forams and mollusc fragments.

Interpretation of cuttings indicates that the basal conglomerate of the Lobo contains abundant clasts of Lower Cretaceous strata. The siliceous sandstones, globigerinid-bearing clasts, and silty shales probably represent Mojado lithologies. Lower Paleozoic clasts are also present and may have been derived from both lower Paleozoic strata and the Hell-to-Finish Formation, which contains abundant lower Paleozoic clasts elsewhere in the region (Mack et al., 1986). Sandstones of all three wells likewise indicate a sedimentary source terrane, although the volcanic arenites of the Bisbee Hills well suggest an increasingly important volcanic provenance with time. Mack and Clemons (1988) noted a similar upsection increase in volcanic arenites in the Lobo Formation at two localities in the Florida Mountains. The northward-fining trends demonstrated between the Saltys and Cockrell wells suggest that the sedimentary source terrane lay to the south.

Victorio Mountains

The Lobo Formation of the Victorio Mountains consists of conglomerate, sandstone, and reddish-brown siltstone. It rests upon a sequence of siltstone and subordinate fine-grained sandstone similar to the nonmarine strata of the Mojado encountered in the subsurface. The basal conglomerate is poorly sorted boulder and cobble conglomerate with clasts of sandstone, limestone attributable to the Lower Cretaceous U-Bar Formation, and siltstone. In addition to these sedimentary clast types, the basal conglomerate contains andesite clasts that resemble andesite of the Hidalgo Formation of the Little Hatchet and Pyramid Mountains. These volcanic clasts become increasingly abundant upsection in the Lobo.

The conglomerates and sandstones of the Lobo are arranged in several upward-fining sequences several hundred feet thick. Conglomerates are crudely bedded to flat bedded, with angular, poorly sorted clasts. They grade to flat-bedded reddish-brown sandstones overlain in turn by interbedded red-brown siltstone and sandstone that form intervals several tens of feet thick. We interpret these associated facies as alluvial fan-braided fluvial-playa depositional environments arranged in retrogradational sequences. The uppermost siltstone and sandstone interval of the Lobo is overlain by flow breccia of altered hornblende andesite. We regard this breccia as the base of the Rubio Peak Formation.

Like the upper sandstone in the Lobo of the Bisbee Hills well, the sandstones of the Lobo in the Victorio Mountains are rich in volcanic lithic grains. A lower Lobo lacking in volcanic grains is absent in the Victorio Mountains. These observations indicate that the volcanic influence was greater to the north than to the south during Lobo deposition or that Lobo deposits did not onlap the area of the Victorio Mountains until late in the history of the basin. Volcanic arenites occur in the upper part of the Lobo north of the Laramide Burro uplift (Fig. 7) and likewise indicate the importance of a volcanic provenance to the north of the study area (Mack and Clemons, 1988).

In the Victorio Mountains, the Rubio Peak Formation is 1,400 ft (430 m) thick. In the Bisbee Hills well, Rubio Peak flows, breccias, and volcaniclastics are 1,800 ft (549 m) thick. In the Cockrell well, 1,900 ft (549 m) of Rubio Peak are truncated beneath basin-fill gravel (Clemons and Lawton, 1991). Thus, the Rubio Peak Formation, like the Lobo, thickens somewhat from north to south in the areas studied.

Klondike Basin—a late Laramide depocenter

The Lobo Formation between the Victorio Mountains and the Cedar Mountain Range forms a southwestward-thickening wedge of nonmarine clastic strata. The wedge is bounded to the southwest by a dominantly reverse fault that emplaced Paleozoic units above the Lobo. The Lobo overlies Lower Cretaceous strata with only slight discordance. In the Bisbee Hills well, Lower Cretaceous strata are missing beneath the Lobo because of either faulting or erosion. Conglomerates with Lower Cretaceous clasts that overlie Paleozoic strata and underlie mid-Tertiary volcanic units in the Cedar Mountain Range may indicate that Lobo strata lapped onto the southern uplifted block; however, the correlation of the conglomerate of the Cedar Mountain Range remains uncertain. North of the Victorio Mountains, the Lobo thins and pinches out onto Precambrian rocks of the Laramide Burro uplift (Seager and Mack, 1986). To the southeast, we speculate that the Lobo continues south of the Florida Mountains, as depicted by Seager and Mack (1986).

The uplifted region that lies south of the Lobo depocenter consists of complexly faulted and elevated Paleozoic and subordinate Mesozoic strata. The uplift is partly exposed in the West Lime Hills, the Cedar Mountain Range, and the Klondike Hills immediately northeast of the Cedar Mountain Range. A northwestward extension of the uplifted terrane was penetrated in the Saltys well. This uplift is termed the Luna uplift (Fig. 7) because of its extensive presence in Luna County.

The Klondike Basin (Fig. 7), defined by the thick wedge of Lobo, was initiated by deposition of conglomerates dominated by Lower Cretaceous and Paleozoic clasts. Volcanic clasts were present at northern

☞

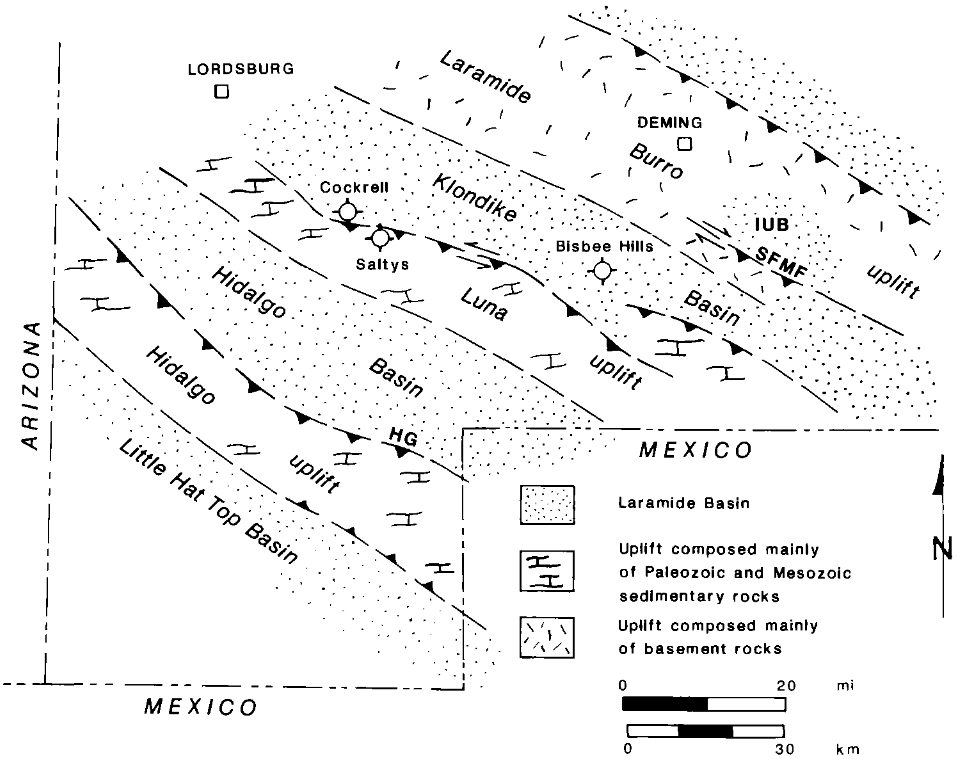


FIGURE 7—Paleogeographic reconstruction of Klondike Basin and other Laramide basins and uplifts of southwestern New Mexico. Margins of the Hidalgo and Laramide Burro uplifts modified from Seager and Mack (1986). The Hidalgo Basin depicted here was termed Ringbone Basin by Seager and Mack (1986) but contains Laramide deposits, including the Skunk Ranch Formation, in addition to the Ringbone Formation (Wilson, 1991). The name change is suggested to avoid confusion regarding distribution of Laramide units. IUB is intra-uplift basin of Mack and Clemons (1988), which contains a thin Lobo section of less than 600 ft (200 m) resting directly on Precambrian to Ordovician rocks. Adjacent south Florida Mountains fault (SFMF) has both reverse and right-lateral components of offset (Brown and Clemons, 1983). Left-lateral offset inferred on northern structural boundary of Luna uplift is based on left-lateral strike-slip faulting in Klondike Hills (Rupert and Clemons, 1990). Left steps inferred on structural trends reflect complex structure in southern part of Florida Mountains (Mack and Clemons, 1988) and West Lime Hills (discussed in text). Right-lateral offset has been interpreted on the north flank of the Hidalgo uplift at Hatchet Gap (HG; Seager and Mack, 1986). The seemingly conflicting displacements are difficult to explain with simple kinematic models and require further study.

localities. The sedimentary rock types that contributed to the conglomerate are present in modern ranges along the Luna uplift; known sources for volcanic clasts lie to the southwest in the Little Hatchet Mountains (Zeller, 1970) and to the west and northwest in the Coyote Hills (Thorman, 1977) and Pyramid Mountains (Thorman and Drewes, 1978). Dominance of sedimentary grain types in sandstones of the wells and volcanic grain types in the Lobo of the Victorio Mountains indicate that the sedimentary source remained important throughout deposition of the Lobo, but that volcanic detritus probably did not come from the south. The Luna uplift was probably the dominant source for clastic detritus in the southwestern part of the basin. The asymmetry and southwest thickening of the basin may be due to loading by the uplift. Analogous load asymmetry is present in Laramide basins of the Rocky Mountain province (Hagen et al., 1985). We infer that dispersal systems parallel to the basin axis carried volcanic detritus from the northwest. The most likely sources of the volcanic grains are the Cretaceous–Paleocene volcanics of the Hidalgo Formation and its correlatives.

The Klondike Basin probably formed in early to middle Eocene time and thus is an example of a late Laramide basin. It formed at the edge of the former Bisbee Basin, where thick sections of Lower Cretaceous strata thin northward in a short distance and pinch out above older strata of the craton (Mack et al., 1986). The Klondike Basin lacks the phase of Late Cretaceous deposition, recorded by the Ringbone Formation, that occurred in the next depocenter to the southwest (Seager and Mack, 1986; Basabilvazo, 1991). Further evidence of the youth of the Klondike Basin is the presence of Hidalgo clasts in the Lobo Formation. The Hidalgo Formation overlies the Ringbone in the Little Hatchet Mountains and may be in part equivalent with the Paleocene–Eocene Skunk Ranch Formation there (Wilson, 1991). Reported ages on the Hidalgo Formation and its possible equivalents range widely: a hornblende andesite flow at the base of the unit in the northern part of the Little Hatchet Mountains has recently yielded an age of 72.14±0.18 Ma by the $^{40}Ar/^{39}Ar$ method (W. C. McIntosh, written communication, November 25, 1991); in the Pyramid Mountains, the Hidalgo has a minimum fission-track age of 54.9±2.7 Ma (Marvin et al., 1978). Therefore, basin development might have begun at any time during that interval, although the volcanic component of basin fill would probably have been much greater than observed if Hidalgo volcanism had been synchronous with formation of the Klondike Basin. Basin development was largely complete before emplacement of the volcanic pile of the Rubio Peak Formation in middle to late Eocene time.

ACKNOWLEDGMENTS—We thank C. F. Kluth, S. N. Nelson, and Chevron Overseas Production, Incorporated, for palynomorph analyses of samples from Cockrell State #1 and Tom Bruce of Marshall Young Oil Company for supplying us with dipmeter logs of the Bisbee Hills Unit #1 and Saltys Unit #1 wells. We also are grateful to Frank Kottlowski and the N.M. Bureau of Mines and Mineral Resources for financial support to do the petrographic analyses. Reviews by S. M. Cather, G. H. Mack, and W. R. Seager substantially improved the manuscript. Theresa Call assisted with drafting of the figures.

References

Basabilvazo, G. T., 1991, Stratigraphy, depositional environments, and sediment dispersal pathways of the Upper Cretaceous Ringbone Formation in the Little Hatchet Mountains of southwestern New Mexico: MS thesis, Las Cruces, New Mexico State University, 158 pp.

Berggren, W. A., Kent, D. V., Flynn, J. J., and Van Couvering, J. A., 1985, Cenozoic geochronology: Geological Society of America, Bulletin, v. 96, pp. 1407–1418.

Bilodeau, W. L., 1982, Tectonic models for Early Cretaceous rifting in southeastern Arizona: Geology, v. 10, pp. 466–470.

Bromfield, C. S., and Wrucke, C. T., 1961, Reconnaissance geologic map of the Cedar Mountains, Grant and Luna Counties, New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map MF–159, scale 1:62,500.

Brown, G. A., and Clemons, R. E., 1983, Florida Mountains section of southwest New Mexico overthrust—a reevaluation: New Mexico Geology, v. 5, pp. 26–29.

Clemons, R. E., 1982, Geology of Massacre Peak quadrangle, Luna County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 51, scale 1:24,000.

Clemons, R. E., and Lawton, T. F., 1991, Petrographic and well log analysis of four exploration wells in southwestern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 381, 97 pp.

Coney, P. J., and Reynolds, S. J., 1977, Cordilleran Benioff zones: Nature, v. 270, pp. 403–405.

Davis, G. H., 1979, Laramide folding and faulting in southeastern Arizona: American Journal of Science, v. 279, pp. 513–569.

Dickinson, W. R., 1981, Plate tectonic evolution of the southern Cordillera; *in* Dickinson, W. R., and Payne, W. D. (eds.), Relations of tectonics to ore deposits in the southern Cordillera: Arizona Geological Society, Digest, v. 14, pp. 113–136.

Dickinson, W. R., Fiorillo, A. R., Hall, D. L., Monreal, R., Potochnik, A. R., and Swift, P. N., 1989, Cretaceous strata of southern Arizona; *in* Jenney, J. P. and Reynolds, S. J. (eds.), Geologic evolution of

Arizona: Arizona Geological Society, Digest, v. 17, pp. 447–461.
Drewes, H., 1971, Geologic map of the Mount Wrightson quadrangle, southeast of Tucson, Santa Cruz and Pima Counties, Arizona: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I–614, scale 1:48,000.
Drewes, H., 1988, Development of the foreland zone and adjacent terranes of the Cordilleran orogenic belt near the U.S.–Mexican border; *in* Schmidt, C. J. and Perry, W. J., Jr. (eds.), Interaction of the Rocky Mountain foreland and the Cordilleran thrust belt: Geological Society of America, Memoir 171, pp. 447–463.
Gillette, D. D., Wolberg, D. L., and Hunt, A. P., 1986, Tyrannosaurus rex from the McRae Formation (Lancian, Upper Cretaceous), Elephant Butte Reservoir, Sierra County, New Mexico: New Mexico Geological Society, Guidebook to the 37th Field Conference, pp. 235–238.
Hagen, E. S., Shuster, M. W., and Furlong, K. P., 1985, Tectonic loading and subsidence of intermontane basins: Wyoming foreland province: Geology, v. 13, pp. 585–588.
Keith, S. B., 1979, Paleosubduction geometries inferred from Cretaceous and Tertiary magmatic patterns in southwestern North America: Geology, v. 6, pp. 516–521.
Kottlowski, F. E., 1960, Summary of Pennsylvanian sections in southwestern New Mexico and southeastern Arizona: New Mexico Bureau of Mines and Mineral Resources, Bulletin 66, 187 pp.
Loring, A. K., and Loring, R. B., 1980, K/Ar ages of middle Tertiary igneous rocks from southern New Mexico: Isochron/West, no. 28, pp. 17–19.
Lucas, S. G., Basabilvazo, G. T., and Lawton, T. F., 1990, Late Cretaceous dinosaurs from the Ringbone Formation, southwestern New Mexico, U.S.A.: Cretaceous Research, v. 11, pp. 343–349.
Lucas, S. G., and González-León, C., in press, Reporte preliminar sobre dinosarios del Cretacio Tardio de la cuenca de Cabullona, Sonora: Universidad de Sonora, Depto. Geologia Boletin, v. 7.
Mack, G. H., and Clemons, R. E., 1988, Structural and stratigraphic evidence for the Laramide (early Tertiary) Burro uplift in southwestern New Mexico: New Mexico Geological Society, Guidebook to the 39th Field Conference, pp. 59–66.
Mack, G. H., Kolins, W. B., and Galemore, J. A., 1986, Lower Cretaceous stratigraphy, depositional environments, and sediment dispersal in southwestern New Mexico: American Journal of Science, v. 286, pp. 309–331.
Marvin, R. G., Naeser, C. W., and Mehnert, H. H., 1978, Tabulation and radiometric ages—including unpublished K-Ar and fission-track ages—for rocks in southeastern Arizona and southwestern New Mexico: New Mexico Geological Society, Guidebook to 29th Field Conference, pp. 243–252.
Miller, H. W., 1964, Cretaceous dinosaurian remains from southern Arizona: Journal of Paleontology, v. 38, pp. 378–384.
Pearce, T. M., 1965, New Mexico place names—a geographical dictionary: Albuquerque, University of New Mexico Press, 187 pp.
Rupert, M. G., and Clemons, R. E., 1990, Stratigraphy and structure of the Klondike Hills, southwestern New Mexico: New Mexico Geology, v. 12, pp. 23–30.
Seager, W. R., and Mack, G. H., 1986, Laramide paleotectonics of southern New Mexico; *in* Peterson, J. A. (ed.), Paleotectonics and sedimentation in the Rocky Mountain region, United States: American Association of Petroleum Geologists, Memoir 41, pp. 669–685.
Seager, W. R., Mack, G. H., Raimonde, M. S., and Ryan, R. G., 1986, Laramide basement-cored uplift and basins in south-central New Mexico: New Mexico Geological Society, Guidebook to the 37th Field Conference, pp. 123–130.
Thompson, S., III, 1982, Oil and gas exploration wells in southwestern New Mexico; *in* Powers, R. B. (ed.), Geologic studies of the Cordilleran thrust belt: Rocky Mountain Association of Geologists, pp. 521–536.
Thorman, C. H., 1977, Geologic map of the Coyote Peak and Brockman quadrangles, Hidalgo and Grant Counties, New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map MF–924, scale 1:24,000.
Thorman, C. H., and Drewes, H. 1978, Geologic map of the Gary and Lordsburg quadrangles, Hidalgo County, New Mexico: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I–1151, scale 1:24,000.
Thorman, C. H., and Drewes, H., 1980, Geologic map of the Victorio Mountains, Luna County, southwestern New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map MF–1175, scale 1:24,000.
Wilson, D. A., 1991, Depositional environments, provenance, and age of the Skunk Ranch Formation, Little Hatchet Mountains, southwestern New Mexico: MS thesis, Las Cruces, New Mexico State University, 87 pp.
Wilson, D. A., Lawton, T. F., and Basabilvazo, G. T., 1989, Stratigraphy and depositional environments of the Skunk Ranch Formation, Little Hatchet Mountains, southwestern New Mexico (abs.): New Mexico Geology, v. 11, p. 63.
Zeller, R. A., Jr., 1970, Geology of the Little Hatchet Mountains, Hidalgo and Grant Counties, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 96, 22 pp. □

Upcoming geologic meetings

Conference title	Dates	Location	Contact for more information
ASPRS/ACSM annual meeting	Feb. 29–March 5	Convention Center Albuquerque	Tech. Appl. Center Univ. of New Mexico Albuquerque, NM 87131 (505) 277-3622
Applied sequence stratigraphy symposium	March 25-27	CSM Golden, CO	Rocky Mtn. Assoc. Geol. 730 17th St., Suite 350 Denver, CO 80202 (303) 573-8621
Permian Basin Section, SEPM field trip	April 9-11	Franklin Mtns. El Paso, TX	PBS-SEPM P.O. Box 1595 Midland, TX 79702 (915) 683-1573
New Mexico Geological Society spring meeting	April 10	Macey Center Socorro, NM	Richard Chamberlin William Haneberg (505) 835-5420 Peter Mozley (505) 835-5311 Socorro, NM 87801
Southwest Section, AAPG meeting	April 12-14	Midland, TX	WTGS P.O. Box 1595 Midland, TX 79702 (915) 683-1573
Coalbed Gas Development, East and West	April 23-24	Santa Fe, NM	Rocky Mountain Mineral Law Foundation 7039 E. 18th Ave. Denver, CO 80220 (303) 321-8100
10th Oil & Gas Conference for Industry and Government	April 27-29	Albuquerque, NM	BLM–NM State Office P.O. Box 27115 Santa Fe, NM 87502

New Mexico Geological Society

Spring Meeting

The New Mexico Geological Society will hold its annual spring meeting on Friday, April 10, 1992 in Macey Center at the New Mexico Institute of Mining and Technology, Socorro, New Mexico. This meeting promotes the dissemination of results of recent research on the geology of New Mexico or adjacent areas. Sessions cover petrology, structural geology, stratigraphy, sedimentology, paleontology, geochemistry, economic geology, and hydrology. Guest speaker is Daniel B. Stephens. General chairpersons are Richard M. Chamberlin, (505) 835-5310, and William C. Haneberg, (505) 835-5808, at the New Mexico Bureau of Mines and Mineral Resources. Registration materials are available from Peter S. Mozley, (505) 835-5311, Geoscience Dept., New Mexico Tech, Socorro, New Mexico 87801.