Jornada Draw fault: A major Pliocene-Pleistocene normal fault in the southern Jornada del Muerto

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Jornada Draw fault: a major Pliocene–Pleistocene normal fault in the southern Jornada Del Muerto

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Abstract

The north–northwest-trending Jornada Draw fault, 40 mi (64 km) long, has displaced the hinge area of the Jornada del Muerto syncline approximately midway between the Caballo and San Andres Mountains. Downthrown to the east, the fault forms the eastern boundary of the Caballo horst and the west boundary of a broad half graben that underlies the east part of the Jornada del Muerto in this area. Maximum stratigraphic separation of 1,850 ft (564 m) was measured from the central segment of the fault, but this decreases toward its termination to the north and probably also to the south. In spite of the comparatively large, apparent vertical component of slip, physiographic evidence for the fault is subtle because of the extensive low-relief pediment that truncates both hanging-wall and footwall rocks. Local low scarps, a series of playa lakes, and Jornada Draw drainage are its principal physiographic expressions. However, sedimentary and volcanic rock formations ranging in age from Pleistocene to Cretaceous are truncated by the fault, and a basaltic cinder cone was constructed on the fault in late Pliocene time. There is no stratigraphic evidence that the fault developed earlier than Pliocene time. Pliocene–Pleistocene strata of the Camp Rice and Palomas Formations are syntectonic and reach a maximum known thickness of 250 ft (76 m) on the hanging-wall block, although greater thicknesses may be present in the subsurface. Thus, the fault apparently formed late in the history of the Rio Grande rift region of south-central New Mexico, probably to help accommodate growing structural relief between the Caballo uplift and Jornada del Muerto syncline. Most recent movement of 30 ft (9 m) along the fault is estimated to be approximately 0.4 Ma. Quaternary offset locally exceeds 100 ft (30 m). The earthquake potential of this fault is considered to be minimal.

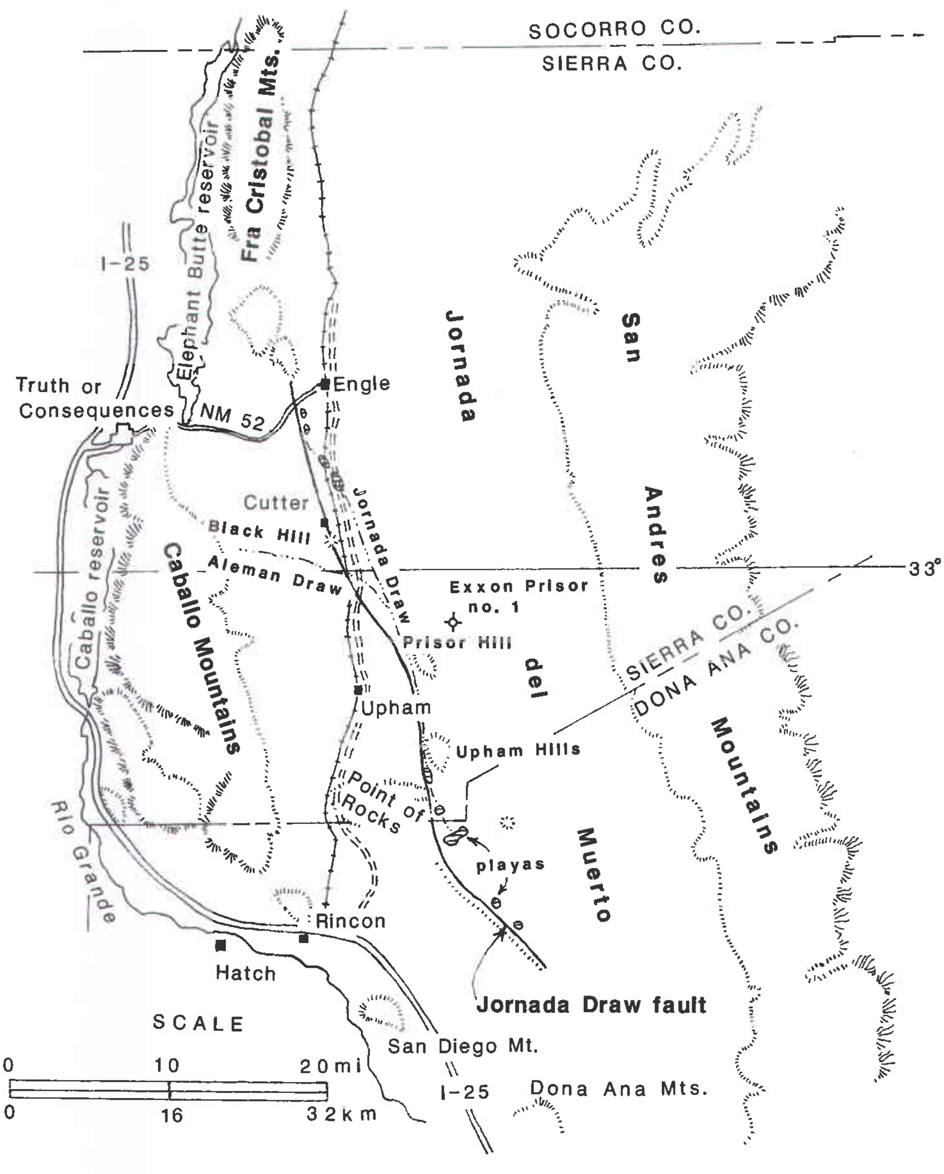

FIGURE 1—Location map of the southern Jornada del Muerto plain and adjacent area.

Introduction

Located between the east-tilted Caballo and west-tilted San Andres fault blocks, the structure of the southern Jornada del Muerto has long been regarded as a simple shallow syncline, trending northward and containing only a thin veneer of upper Cenozoic alluvium (Shumard, 1859; Darton, 1928; Kelley and Silver, 1952; Kelley, 1955; Seager, 1986; Seager et al., 1987). Drilling tests for petroleum at wide-

Also in this issue

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Albuquerque Basin—studies in hydrogeology ly scattered locations throughout the Jornada del Muerto seemed to confirm this interpretation (Foster and Stipp, 1961; Woodward et al., 1975). An exception to this view was portrayed on a geologic map of the Rio Grande rift (Woodward et al., 1978), which showed a major normal fault transecting the syncline near its hinge, passing through Point of Rocks, and extending northward for 20 mi (32 km). However, the existence of the fault was based on the mistaken interpretation that a thick sequence of red beds encountered in the Exxon No. 1 Prisor well, located 4 mi (6 km) east of the fault (Fig. 1), was upper Tertiary rift sediments. Seager et al. (1987) later correctly identified the red beds as lower Tertiary Love Ranch Formation, and the fault was removed from subsequent maps (Seager, 1986).

Recent detailed mapping of the Caballo Mountains and western flank of the Jornada del Muerto (Mack and Seager, in press; Seager and Mack, in press) has reestablished the presence of a major, through-going normal fault located approximately in the position of the fault shown on the Woodward et al. (1978) map of the Rio Grande rift. Because Jornada Draw, an axial drainage of the southern Jornada del Muerto, closely follows the fault, we have named it the Jornada Draw fault (Fig. 1).

The Jornada Draw fault passes through the center of the spaceport site, a facility whose proposed location was announced publicly in 1994. Consequently, our goal in this paper is not only to describe the evidence for the fault, its geometry and geologic history, but also to determine the most recent movement and to assess its earthquake potential.

General features and regional relationships

The Jornada Draw fault is a through-going normal fault that extends from the Engle area south–southeastward across the southern Jornada del Muerto to south of Point of Rocks hills, a distance of nearly 40 mi (64 km) (Fig. 1). Where it crosses Aleman Draw, the fault is exposed, dipping approximately 60° eastward. A few miles northwest of Engle the fault terminates against a small horst of Cretaceous strata, considered by Mack and Seager (1995; in press) to be a southern extension of the Fra Cristobal uplift and named by them "central horst" (Fig. 2). At its southern end, the fault, identified here by a low degraded piedmont scarp, is lost amidst desert plains, covered by upper Pleistocene and Holocene alluvium.

Although the three-dimensional geometry of the Jornada Draw fault is poorly constrained, relationships west of Engle suggest the fault in that area may be listric (Fig. 3). Nearly undeformed piedmont-slope conglomerate of the Pliocene to middle Pleistocene Palomas Formation caps the sequence of sedimentary strata in the footwall, whereas the same Palomas strata in the hanging wall dip approximately 1° westward into the fault. This "reverse drag"—the different tilt of hanging wall relative to footwall—is consistent with listric geometry of the fault surface in that area.

From a regional perspective, the Jornada Draw fault outlines the mutual boundary between two major late Tertiary fault blocks: the eastward-tilted Caballo Mountains horst that comprises the footwall, and a broad, shallow half graben that constitutes the hanging wall. The updip part of the west-dipping, hanging-wall strata form the San Andres Mountains. Thus, the commonly accepted view that the southern Jornada del Muerto is a broad, shallow, simple syncline must be modified to the extent that the hinge area and western limb of the syncline is broken by a major down-to-the east normal fault—the Jornada Draw fault. This structure in effect converts the eastern limb of the syncline into a half graben (Fig. 2).

Physiographic expression

Because it crosses the broad, nearly featureless plains of the Jornada del Muerto, the physiographic expression of the Jornada Draw fault is subtle. Low piedmont scarps mark the southern and northern limits of the fault, and the Point of Rocks hills are remnants of footwall mountains or hills. Low hills of bedrock, elongated parallel to the fault, such as the Upham and Prisor Hills, are locally exposed in the hanging wall, but in general, the position of the fault is obscured by pediment and fan surfaces that cross the fault with only subtle slope breaks. However, the course of the fault is clearly marked by Jornada Draw and by a series of eight playa lakes, all located on the hanging-wall side only 0.5 to 2 mi (0.8 to 3 km) from the fault (Fig. 1), positions established by Quaternary subsidence along the fault. Near Cutter, the fault is marked by a late Pliocene (?) cinder cone, Black Hill, which was constructed astride the fault.

Stratigraphic separation

Although the physiographic expression of the Jornada Draw fault is subtle, truncation of bedrock units by the fault, as seen on a geologic map (Fig. 2), is not. Formations ranging in age from Cretaceous to Pleistocene are truncated, and this provides a basis for estimating amount of stratigraphic separation using either thicknesses encountered in the Exxon No. 1 Prisor well or field measurements. At the north end of Prisor Hill, uppermost beds of the Love Ranch Formation (early Tertiary) are nearly juxtaposed with upper units of the Bell Top Formation (Oligocene), indicating stratigraphic separation equal to the thickness of the Palm Park and Bell Top Formations, approximately 1,850 ft (564 m). McRae strata (Late Cretaceous) at Aleman Draw are in fault contact with middle(?) parts of the Love Ranch Formation, suggesting approximately 1,000 to 1,500 ft (305 to 457 m) of separation at that locality. Near the north tip of the fault only 100 to 200 ft (30 to 61 m) of separation is indicated by juxtaposed upper and lower McRae beds. The data suggest decreasing separation northward along the fault from a maximum near the central part. The absence of slickenside data or piercing points allows no estimate of slip.

Offset of middle Pleistocene strata and their associated constructional surfaces is generally less than stratigraphic separation of Cretaceous and Tertiary formations. For example, just north of the Truth or Consequences–Engle highway NM-52 (Figs. 1, 3), offset of upper beds of the Palomas Formation is only 15 to 20 ft (4.5 to 6 m), although two miles farther south

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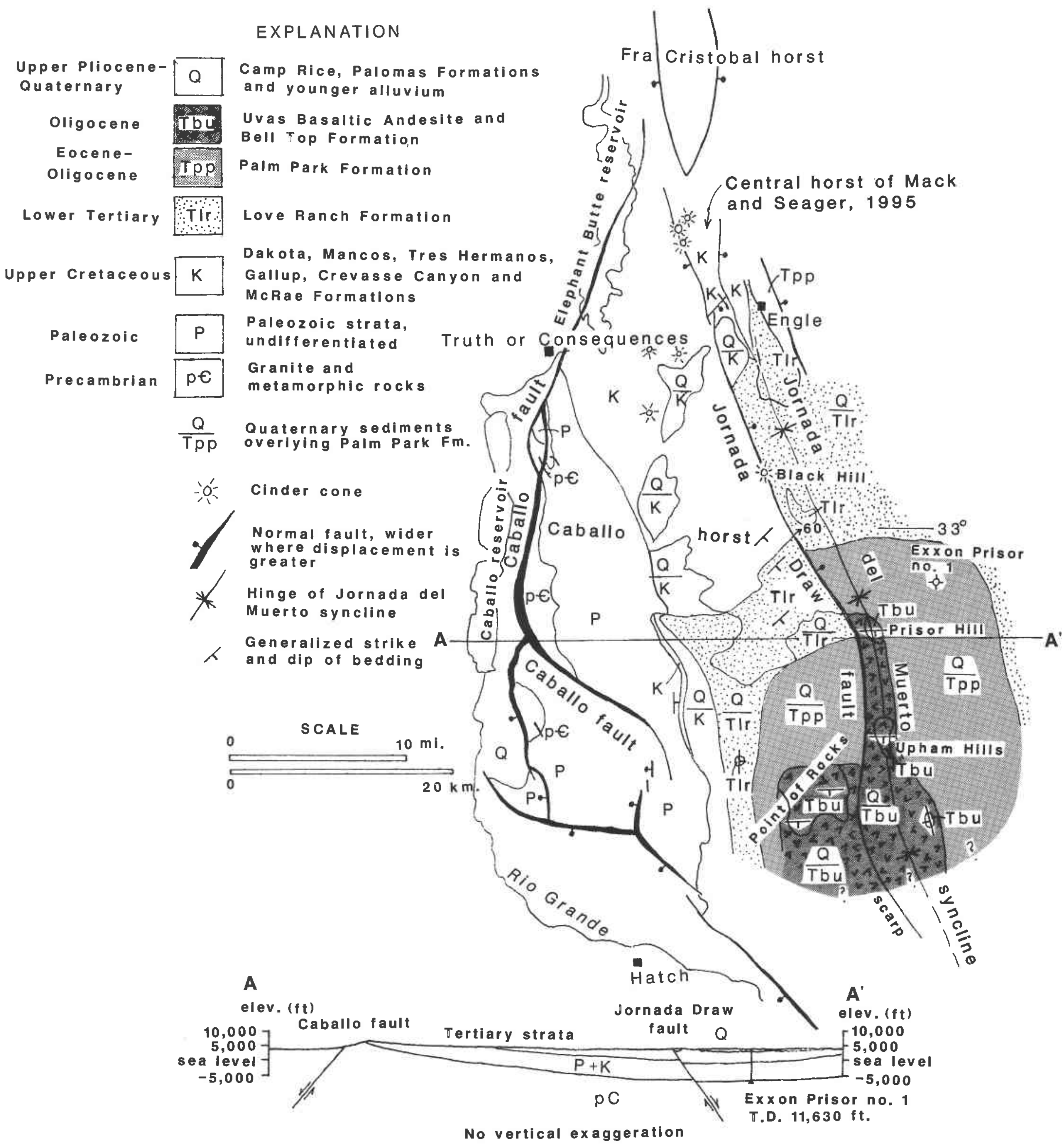

FIGURE 2—Generalized geologic map of Jornada Draw fault and adjacent areas, adapted from various geologic quadrangle maps of the Caballo Mountains (scale 1:24,000) by Seager and Mack.

displacement of the top of the formation is approximately 100 ft (30 m). South of Point of Rocks, the La Mesa surface of middle Pleistocene age, constructional top of the Camp Rice Formation (Pliocene to middle Pleistocene), is offset approximately 30 ft (9 m). These displacements indicate the magnitude of post-middle Pleistocene movement on the fault.

Syntectonic and post-tectonic basalt and sedimentary rocks

Although possible Miocene or older syntectonic rocks may lie buried and undetected on the downthrown side of the Jornada Draw fault, the only exposed section of syntectonic rocks is Pliocene and Pleistocene in age. From Aleman Draw northward the rocks are correlated with the Palomas Formation (Lozinsky and Hawley, 1986a, b); south of Aleman Draw they are arbitrarily assigned to the Camp Rice Formation (e.g., Seager et al., 1971; Mack and Seager, 1990). Consisting primarily of piedmont-slope gravel and conglomerate, the two formations represent alluvial-fan deposits and pediment ve- ☞

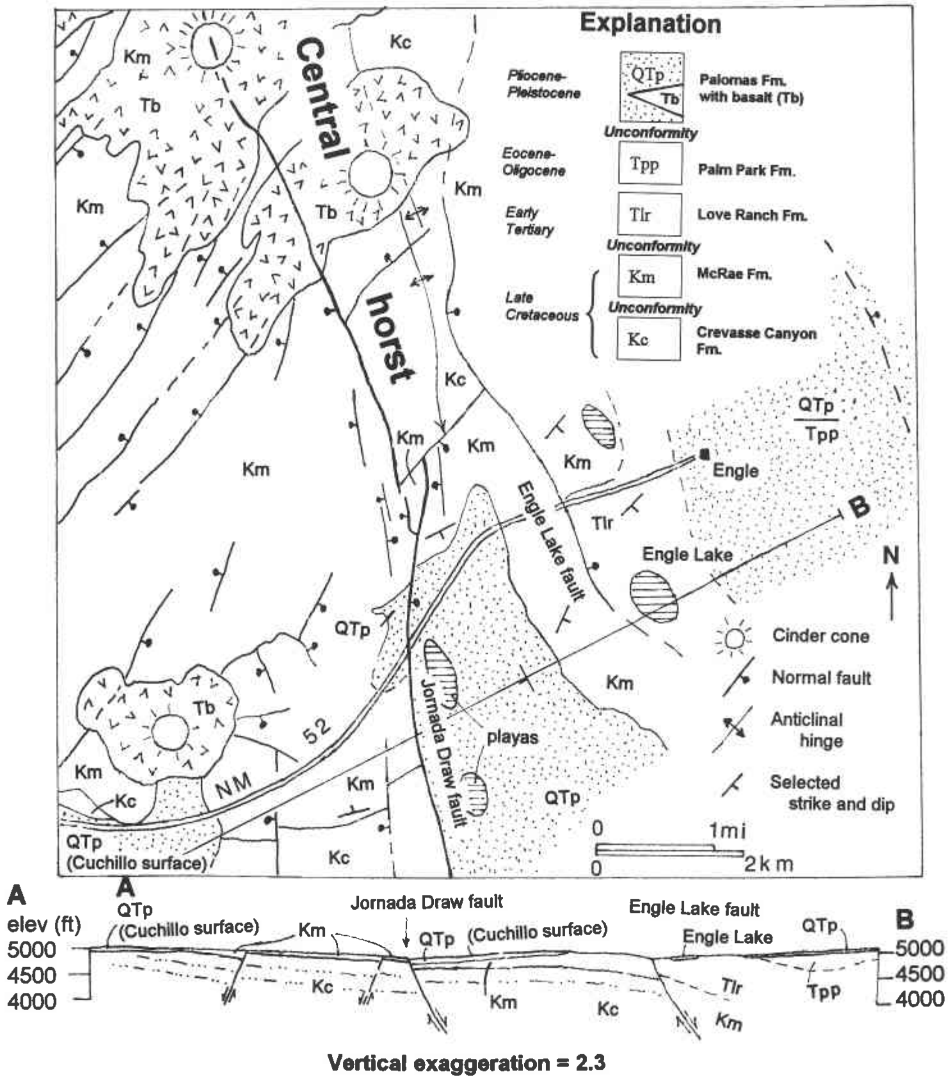

FIGURE 3—Generalized geologic map and section of northern termination of the Jornada Draw fault near Engle, adapted from Mack and Seager, 1995; in press.

neers derived from the Caballo, San Andres, and Fra Cristobal uplifts, as well as alluvium probably washed from the footwall of the Jornada Draw fault. In addition, a significant part of the Camp Rice Formation, south of Point of Rocks, consists of fluvial sand and sandstone deposited by the ancestral Rio Grande. Consistent with syntectonic sedimentary deposits, there are significant differences in thickness of the Palomas/Camp Rice sections between hanging-wall and footwall depositional sites.

From Point of Rocks northward, Palomas and Camp Rice piedmont-slope deposits on the footwall of the Jornada Draw fault are no more than pediment veneers, generally less than 30 ft (9 m) thick; they locally bury broad tracts of the footwall but also have recently been stripped from wide areas, particularly from the northern part of the footwall. In contrast, as much as 250 ft (76 m) of basin fill, interpreted to be mostly if not entirely Camp Rice/Palomas fan gravel and conglomerate, was drilled in the Exxon No. 1 Prisor well, located on the hanging wall within 4 mi (6 m) of the fault. These strata may be as old as 3.4 to 4.2 Ma, the age of basal Camp Rice/Palomas strata in adjacent parts of the Rio Grande valley (Repenning and May, 1986; Mack et al., 1993). Elsewhere on the hanging wall, scattered outcrops of lower to middle Tertiary volcanic or clastic rocks suggest uniformly thin basin fill, on the order of a few hundred feet, but it is conceivable that locally as much as 1,850 ft (564 m) of basin fill, equal to the stratigraphic separation, might be present in deep paleovalleys. Post-tectonic alluvial fan and arroyo sediments are late Pleistocene and Holocene in age and are uniformly thin (30 ft; 9m) across both hanging-wall and footwall blocks.

Thin, undeformed basalt flows are locally interbedded with the Palomas Formation on the footwall of the Jornada Draw fault, and a basaltic cinder cone, Black Hill, was constructed astride the fault (Fig. 2). Undated, these basalts may be approximately 2.1 Ma old based on correlation with dated flows and cones north of Engle that are 1) lithologically identical, 2) occupy similar geomorphic positions, and 3) exhibit the same degree of erosion and soil development (Bachman and Mehnert, 1978). The basalt at Black Hill clearly invaded the fault and post-basalt movement has displaced the cone 50 to 100 ft (15 to 30m).

Age of faulting

The Jornada Draw fault appears to have formed late in the evolution of the Rio Grande rift. Upper Oligocene and Miocene basin-fill deposits are seemingly absent or at least very thin on the hanging-wall block of the fault, suggesting either that the fault was not initiated at those times, or that, if present, alluvium was transported out of the half graben by an axial drainage system. Although we recognize the probable existence of axial drainage along the hinge of the Jornada del Muerto syncline throughout Miocene time (*see* Discussion), we prefer to interpret the Jornada Draw fault as a younger structure on the basis of the distribution and thickness variations of syntectonic Camp Rice/Palomas basin-fill deposits. At any rate, by 2.1 Ma ago fault movement had commenced, the fault being utilized for ascent of basaltic magma to the surface to form Black Hill cinder cone.

Our attempt to bracket the age of most recent movements of the Jornada Draw fault comes from studies of the scarps at the northern and southern ends of the fault. At both localities the constructional top of the Camp Rice/Palomas Formation (La Mesa surface/Cuchillo surface) is offset—as much as 100 ft (30 m) along the northern segment, approximately 30 ft (9 m) along the southern segment. Mack et al. (1993) have bracketed the age of the La Mesa surface between 0.9 to 0.7 Ma; fault movement is therefore younger than these dates.

A few miles south of Point of Rocks, the southern scarp is highly degraded, exhibiting a slope angle of 20° or less (Fig. 4). Fluvial sand and sandstone of the Camp Rice Formation is exposed in the scarp, modified by stage III to incipient stage IV soil carbonate (Gile et al., 1981) that developed on the scarp (Fig. 5a, b). The soil contains numerous angular fragments of stage IV soil carbonate derived from upslope outcrops of the soil beneath the La Mesa surface at the head of the scarp (Fig. 5b). The scarp-slope soil extends down the scarp, crosses the presumed position of the fault, and overlies a thin wedge of loamy sediments at the base of the scarp (Fig. 6). Below these sediments, the La Mesa surface and its associated stage IV soil carbonate is locally exposed on the hanging wall of the fault.

Stage III or incipient stage IV soils require hundreds of thousands of years to form (Gile et al., 1981). Hawley (1978) estimated that stage III soils associated with oldest Tortugas fan deposits and surfaces

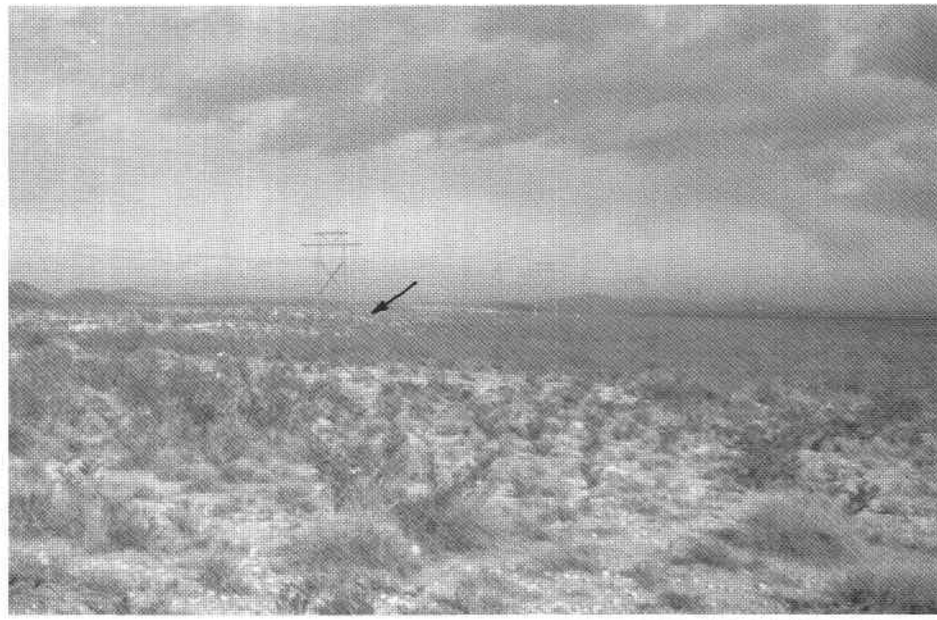

FIGURE 4—Photo looking northwestward along degraded fault scarp (arrow) in footwall of Jornada Draw fault near its southern termination. Camp Rice fluvial sand and sandstone forms the scarp, which is also capped by stage IV soil carbonate associated with the La Mesa surface, Distant hills are Point of Rocks.

near Las Cruces may have formed over the last 400,000 years or more. By analogy we estimate the southern scarp described above to be no younger than 400,000 years. Fault movement may thus be bracketed between a maximum of 0.9 to 0.7 Ma, the age of the La Mesa surface, and a minimum of 0.4 Ma, the inferred age of the soil on the scarp slope. However, the angular fragments of stage IV La Mesa carbonate soil contained in the slope soil suggest that the La Mesa surface was stable for hundreds of thousands of years prior to fault movement. Consequently, we regard latest movement on the Jornada Draw fault to be much closer to 0.4 Ma than to 0.7-0.9 Ma.

Discussion

Mack et al. (1994) presented evidence that uplift of the Caballo range was initiated in latest Oligocene or early Miocene time, shortly after 27.4 Ma. Uplift was accompanied by eastward tilting of the range. Large volumes of fan alluvium were transported westward into a complementary half graben as well as eastward across the paleo dip slope of the range. Initial uplift dates for the San Andres range have not been documented, but Seager (1981) suggested initial uplift of the Organ Mountains began about 28 Ma, based on fanglomerate interbedded with Uvas Basaltic Andesite flows exposed in fault blocks along the east flank of the range. Assuming the San Andres uplift was initiated concurrently with the Organ uplift and tilted westward, then the Jornada del Muerto syncline, located between fault blocks with opposing dips, was also initiated in late Oligocene or early Miocene time. However, there are no "early rift" basin-fill deposits correlative with the Hayner Ranch or Rincon Valley Formations (Mack et al., 1994) known from outcrops or drill holes along the trough or flanks of the syncline. The alluvial deposits that were transported eastward and westward down the dip slopes of the San Andres and Caballo uplifts must have been swept southward, down the plunge of the syncline, by an axial flu- ☞

FIGURE 5A—A stage III to incipient stage IV soil carbonate exposed on fault scarp shown in Fig. 4. Outcrops are on sidewall of arroyo cut into the scarp.

FIGURE 5B—Close-up of stage III-incipient stage IV soil shown in Fig. 5A. Note angular, nearly white fragments of soil carbonate interpreted to be transported clasts of stage IV soil carbonate related to the La Mesa surface.

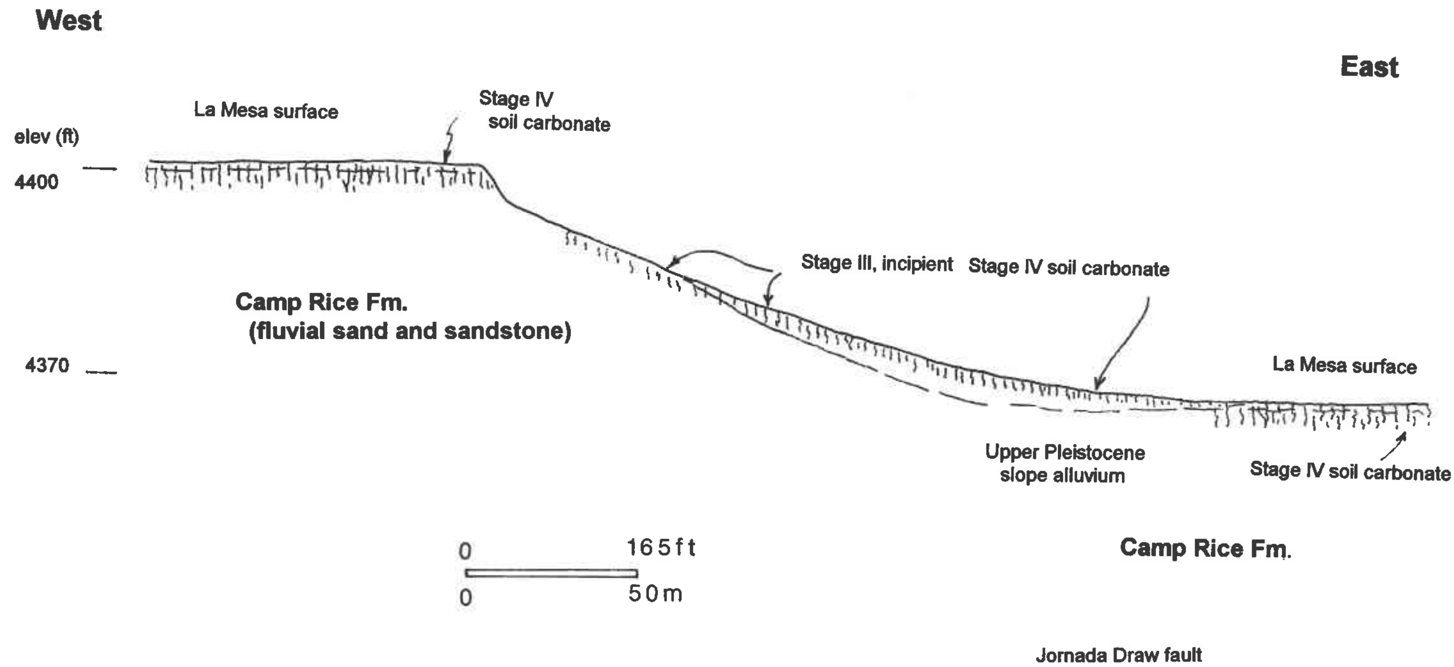

FIGURE 6—Field sketch showing stratigraphic-geomorphic-soil relationship on the fault scarp at the southern end of the Jornada Draw fault.

vial or arroyo system, probably to be deposited in deep half grabens located in the San Diego Mountain area and along the north flank of the Doña Ana Mountains, areas where Hayner Ranch and Rincon Valley sedimentary rocks are known to be thick. Current direction indicators and provenance data from these rocks at San Diego Mountain indicate sources to the north and east, and some were derived in Miocene time directly from the eastern dip slope of the Caballo Mountains (Mack et al., 1994).

There is little evidence from basin-fill deposits that the Jornada Draw fault was initiated more than two or three million years before emplacement of the 2.1 Ma (?) basalt that intrudes the fault at Black Mountain. Indeed, fault truncation of southward-dipping formations along the hinge of the Jornada del Muerto syncline (Fig. 2) indicates the syncline and its southward plunge were already established when the Jornada Draw fault was initiated. Because the only known or inferred basin-fill deposits that are syntectonic with the fault are the Camp Rice/Palomas Formation, we believe that the fault is largely Pliocene and Pleistocene in age, a relatively late developing structure in the Rio Grande rift. Mack et al. (1994) and Seager et al. (1984) have documented pulses of new block faulting and reactivation of old faults at (1) early Oligocene (35 Ma); (2) late Oligocene to early Miocene; (3) middle to late Miocene; and (4) late Miocene (9.6 to 7.1 Ma). The Jornada Draw fault may represent the latest stage of new faulting in Pliocene time.

Why was the fault initiated so late in rift history and why did it form near the hinge of the Jornada del Muerto syncline? Stratigraphic evidence (Mack et al., 1994) indicates both uplift of the Caballo block and complementary downwarping of the Jornada del Muerto syncline began in late Oligocene or early Miocene time. Structural relief between the two continued to grow throughout the Miocene and by late Miocene time approached 13,000 ft (3.96 km). Perhaps the Jornada Draw fault was initiated to help accommodate the growing structural relief between the Caballo uplift and Jornada del Muerto syncline. The geometry of the fault is consistent with this hypothesis: it is downthrown toward the synclinal hinge; it is parallel with the Caballo uplift boundary faults; its throw decreases both to the north and south in concert with the decreasing structural elevation of the Caballo fault block; and the northern and southern terminations of the fault approximately match the limits of the Caballo uplift. Consequently, both the tectonic evolution of the Caballo uplift and Jornada del Muerto syncline, as well as the geometry of the Jornada Draw fault, are compatible with the hypothesis that the fault formed late in rift history to help facilitate the differential rise of the Caballo block and subsidence of the syncline.

Although movement on the Jornada Draw fault has continued into the late Pleistocene, producing offsets of as much as 100 ft, the fault has apparently been inactive for approximately the last 0.4 Ma. There is no evidence for latest Pleistocene or Holocene movement. Consequently, we view the fault as posing little earthquake risk, at least for the near future. This assessment should be welcomed by those who would like to establish a spaceport in the area.

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New Mexico Geological Society

1995 Fall Field Conference: Santa Fe

The New Mexico Geological Society announces its 46th Annual Fall Field Conference on September 27–30, 1995, in Santa Fe, New Mexico. Conference headquarters will be the High Mesa Inn. Santa Fe is located in a dramatic and diverse geologic setting, in the borderland between the Rio Grande rift and the Southern Sangre de Cristo Mountains.

Participants will convene in Santa Fe on the evening of September 27, 1995 for an icebreaker prior to the three-day field conference. Travel will be in first-class buses for the first two days and by personal vehicle on day three.

Day 1 will tour northward from Santa Fe into the southern Española Basin, along US–84 through Tesuque, Cundiyo, Española, and Abiquiu. Highlights will include the structure of the southern Española Basin, mountain-front neotectonics, a visit to an adobe factory, geophysical investigations along the western rift margin, Santa Fe Group stratigraphy and paleontology, the Abiquiu Formation type-section, Quaternary history of the lower Rio Chama, and environmental geology. Day 1 will end at Ghost Ranch with a tour of the museum, the dinosaur quarries, and a redrock barbecue.

Day 2 will follow the Santa Fe Trail around the southern end of the Sangre de Cristo Mountains toward Las Vegas. Highlights will include the Picuris–Pecos fault and Tijeras–Cañoncito fault, Early Proterozoic mylonites and plutons of the southern Sangre de Cristo Mountains, Glorieta Mesa, Laramide structures, the Mesozoic section in the Las Vegas sub-basin, and environmental problems caused by old mining operations along the Pecos River. The annual banquet and keynote address by famed historian Marc Simmons will be held in Santa Fe after the tour.

The Day 3 caravan tour focuses on the transition zone between the Española Basin and the Albuquerque Basin, south of Santa Fe. Highlights will include a visit to the Tiffany turquoise mine, a tour of the studio and stone sculpture garden of Allan Houser, Tertiary stratigraphy and gold mineralization in the Ortiz Mountains, deformation and sedimentation associated with Tertiary intrusions, early rift sedimentation, and the northern Tijeras–Cañoncito fault zone.

Maureen Wilks is registration chairman—please help her by registering early. Registration is limited to the first 200 paid applicants. The registration fee of $175 (member), $270 (member and spouse, 1 guidebook), $200 (nonmember), or $350 (nonmember and spouse, 1 guidebook) includes 1995 NMGS guidebook, icebreaker with food and adult beverages, banquet at High Mesa Inn, two days of bus transportation, three lunches and beverages, barbecue, and museum and quarry tours at Ghost Ranch. Please send inquiries to: Maureen Wilks, NMGS Registration Chairman, NM Bureau of Mines, Socorro, NM 87801, phone (505) 835-5420, FAX (505) 835-6333, email mwilks@gis.nmt.edu.

High-country fall colors should be at their peak, and we look forward to seeing you in Santa Fe.

Paul Bauer
Field Conference Chairman

Field Conference Schedule

Wednesday, September 27 – Registration Day

4:00 p.m.– 8:00 p.m.	Registration at High Mesa Inn, Cerrillos Rd., Santa Fe.
5:30 p.m.– 9:00 p.m.	Icebreaker and exhibits at High Mesa Inn, Santa Fe.

Thursday, September 28 – First Day

7:30 a.m.	Buses depart from High Mesa Inn, Santa Fe.
12:00 noon	Lunch provided at Stop 3.
5:00 p.m.	Arrive at Ghost Ranch for tour and barbecue.
8:00 p.m.	Return to High Mesa Inn, Santa Fe.

Friday, September 29 – Second Day

7:30 a.m.	Buses depart from High Mesa Inn, Santa Fe.
12:00 noon	Lunch provided at Stop 3.
5:30 p.m.	Return to High Mesa Inn, Santa Fe.
6:30 p.m.	Banquet at High Mesa Inn, Santa Fe.
8:00 p.m.	Speaker: Marc Simmons, Historian

Saturday, September 30 – Third Day

7:30 a.m.	Caravan departs from High Mesa Inn, Santa Fe.
12:00 noon	Lunch provided at Stop 4.
3:00 p.m.	Field conference ends at Ortiz Mountains.