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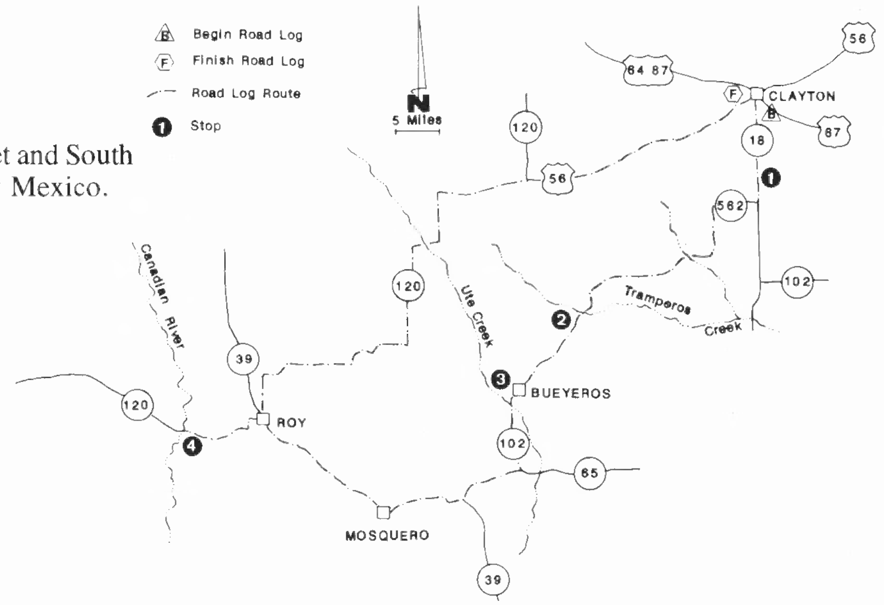
SECOND-DAY ROAD LOG, FROM CLAYTON TO CLAPHAM, MIERA, BUEYEROS, MOSQUERO, ROY, YATES AND BACK TO CLAYTON

SPENCER G. LUCAS, ADRIAN P. HUNT, BARRY S. KUES, FREDERICK D. TRAUGER and JOHN HOLBROOK

FRIDAY, SEPTEMBER 25, 1987

Assembly point: Intersection of Locust Street and South First Street, Clayton, New Mexico.
Departure time: 7:45 a.m.
Distance: 208.3 miles
Stops: 4



SUMMARY

Today's route will traverse the High Plains south and west of Clayton and the Canadian Escarpment to examine: (1) Ogallala Formation stratigraphy, (2) the Bueyeros CO_2 field, (3) Cretaceous and Jurassic stratigraphy and (4) the geohydrology of the Roy area.

From Clayton we first proceed due south to Stop 1 at excellent exposures of the Ogallala Formation in Sand Draw. Continuing west from here, we encounter, and then parallel, the northernmost end of the Canadian Escarpment in Union County. Along the escarpment, at Stop 2 north of Bueyeros, we examine Lower Cretaceous strata. Soon thereafter, at Bueyeros, over lunch, discussion will focus on the Bueyeros CO_2 field. Continuing west, we climb the Canadian escarpment at Mosquero and then traverse the High Plains to Roy. From Roy we continue west, dropping into the Canadian River Valley. Here, at the fourth and final stop, the Jurassic strata exposed in the canyon walls and the geohydrology of the Roy area are highlighted. Returning to Roy, we proceed north and east across the High Plains to Clayton, where today's field trip ends.

Mileage

0.0 Depart from intersection of Locust Street and S First Street (US Highway 87) across from Sunset Motel by **turning right to proceed N** on US-87. **0.5**

0.5 **Stop light** at intersection of First and Main Streets (NM-18). **Turn left. 0.1**

0.6 **Cross railroad tracks** and then **bear left** on NM-18. **0.1**

0.7 **Stop sign** at corner of Court Street and First Avenue. **Turn left** to pass in front of Union County courthouse (Fig. 2.1) and proceed S on NM-18. **0.5**

1.2 Road curves left. **0.2**

1.4 Road curves right. **0.5**

1.9 Leaving Clayton. Sierra Grande is visible in the distance at 4:00. The highway is now on the High Plains. **2.1**

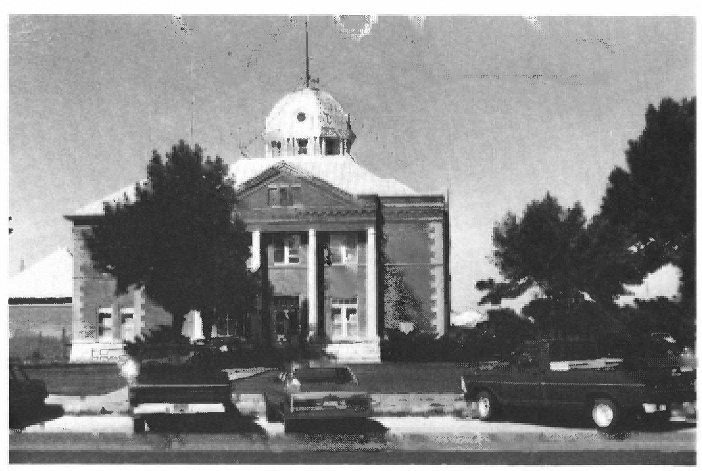


FIGURE 2.1. Union County courthouse, Clayton, New Mexico.

4.0 Descend from the Clayton basalt flow into Perico Creek. The Graneros Shale is exposed in the creekbed to the right overlain by Ogallala Formation (note gravel pit). Clayton basalts cap ridge to left. The upland surface around Clayton is dominated by the Upper Cenozoic Ogallala Formation (Fig. 2.2). Basalts around Clayton are some of the easternmost flows of the Clayton basalts. Older exposed strata are limited to the Graneros Shale, Romeroville Sandstone and Pajarito Formation, of Cretaceous age. **0.6**

4.6 Bridge over Perico Creek. **0.4**

5.0 Roadcuts in Ogallala Formation, next 0.2 mi. **0.4**

5.4 Road to Clayton landfill on right. **1.7**

7.1 Cross tributary of Sand Draw. **0.6**

7.7 Highway curves to right. **0.4**

8.1 Note Ogallala roadcut on right as we descend into Sand Draw. **0.2**

8.3 Bridge over Sand Draw. Graneros Shale exposed in creek on left and right. **STOP 1,** just past bridge. Just east of the highway, in the creek banks of Sand Draw, is Frye

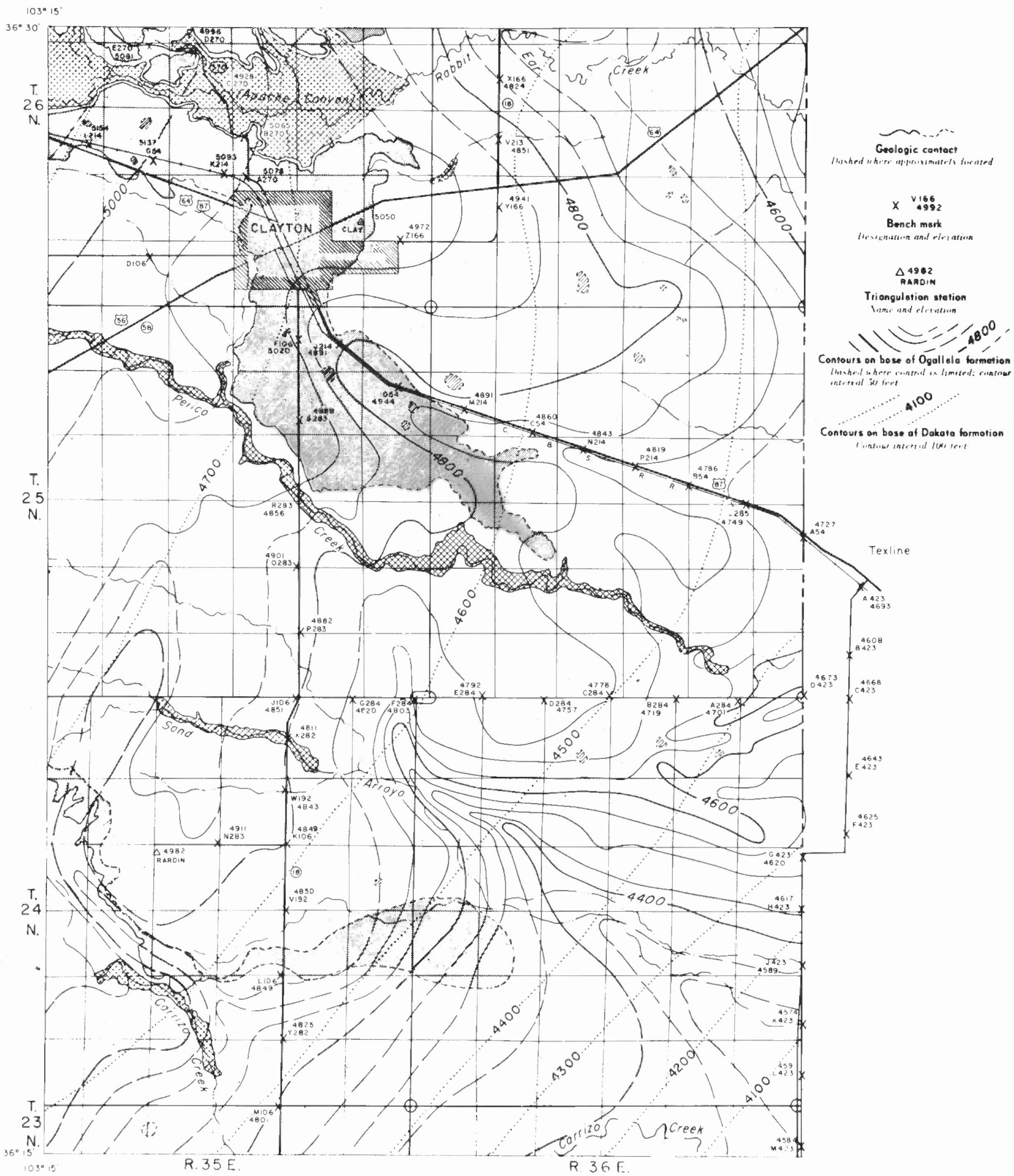


FIGURE 2.2. Geologic map of the Clayton quadrangle (from Baldwin and Bushman, 1957). Blank area is Ogallala Formation and younger deposits; heavily shaded areas are Clayton basalts; stippled areas are Cretaceous strata.

et al.'s (1978) Clayton south section of the Ogallala Formation. Here (SW$^{1}/_{4}$, sec. 2, T24N, R35E), approximately 30 ft of the Ogallala crop out and are dominantly calcareous sandstone with nodular calcrete capped by about 3 ft of pisolitic limestone (Fig. 2.3). Calcareous sandstone about in the middle of the exposed section contains fossil molluscs and seeds (Fig. 2.4). The molluscs are the pelecypod *Pisidium casertanum* and the pulmonate gastropods *Lymnaea dalli, L. parva, L. bulimoides, L. claytonensis, Gyraulus parvus, G. circumstriatus, Ferrissia parallela, F. shimerii, F. tarda, Physa anatina, Euconulus fulvus, Hawaiia miniscula, Succinea grovenori, S. gelida, Gastrocopta pilsbryana, G. cristata, G. debilis, G. arena, Pupoides albilabris, P. modicus, P. hordaceous, P. inornatus, Pupilla blandi, Vertigo milium* and *Vallonia perspectiva* (Leonard, 1977; Leonard and Frye, 1978). The plants are *Panicum elegans* (a millet grass), *Celtis wilsoni* (a hackberry) and the borages *Biorbia microendocarpica, B. levis* and *B. papillosa*. According to Leonard and Frye (1978), these fossils suggest a more stable climate during Ogallala deposition with slightly greater average annual rainfall, one lacking the extreme hot, dry summers now found on the High Plains of northeastern New Mexico. **After the stop, continue S on NM Highway 18. 0.9**

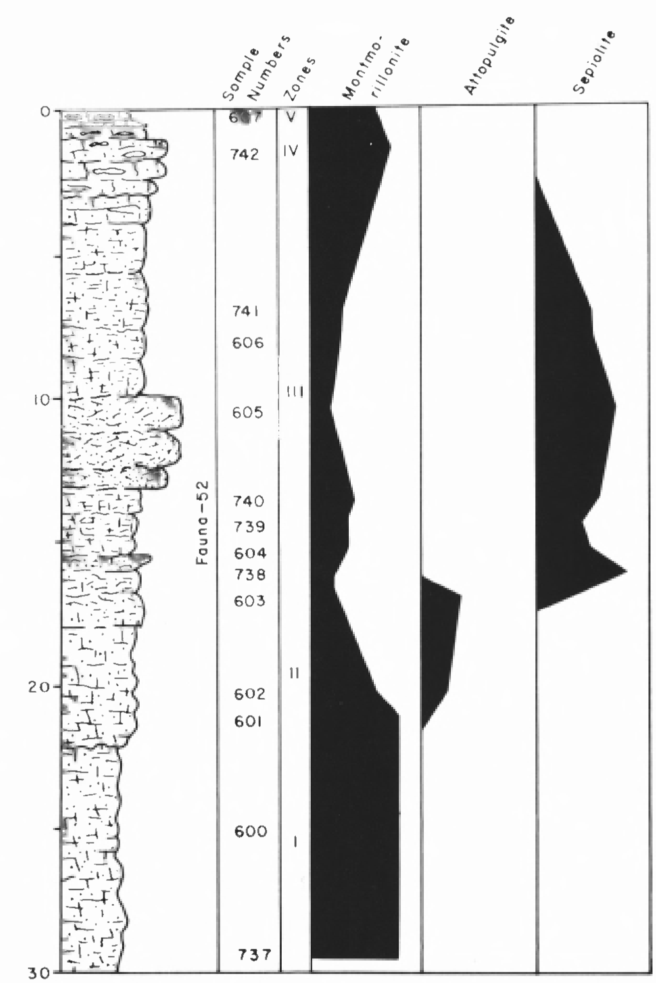


FIGURE 2.3. The Clayton south section of the Ogallala Formation at Stop 1 (from Frye et al., 1978). Thickness in ft is indicated on the left of the diagram, "Fauna-52" in the center of the diagram indicates the fossiliferous interval, and the distribution of clay-mineral zones I–V is indicated.

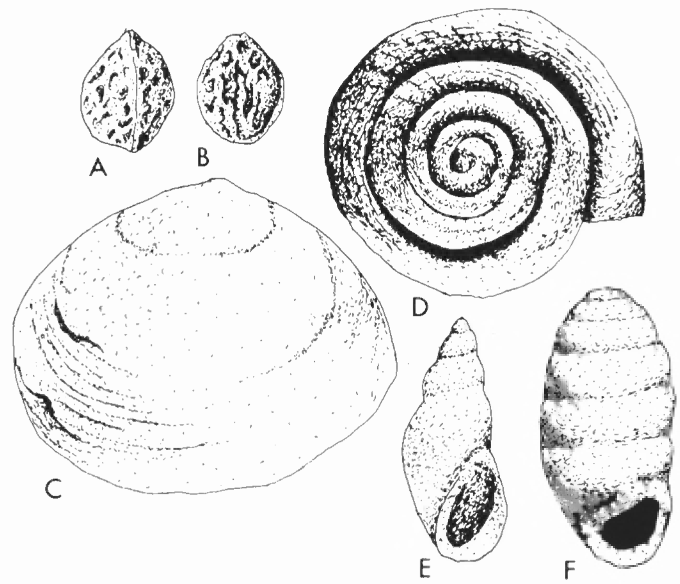


FIGURE 2.4. Some fossils from the Ogallala Formation at Stop 1. A,B, *Celtis* (hackberry seeds), smooth (A) and rugose (B) forms. C, *Sphaerium*. D, *Helicodiscus*. E, *Lymnaea*. F, *Pupilla*. Drawings by Randy Pence.

9.2 Ogallala Formation in creek on left and right. **3.8**

13.0 **Junction** with NM Highway 562. **Turn right** and proceed west toward Thomas. **0.1**

13.1 Cattleguard. **0.2**

13.3 Rabbit Ear Mountain at 3:00 on skyline. **0.2**

13.5 Cattleguard and ranch on right. **0.3**

13.8 Highway descends into Carrizo Creek. **0.2**

14.0 Ogallala Formation on right (Fig. 2.5A). **0.2**

14.2 Unpaved road to left to gravel quarry. Note the Ogallala Formation and Clayton basalts, which are exposed upstream. **0.1**

14.3 Cross bridge. **0.1**

14.4 Note reddish Pleistocene sand, silt and soil above Ogallala Formation to left (Fig. 2.5B). **0.8**

15.2 The highway is again on the High Plains surface. **4.8**

20.0 Highway makes **sharp turn to left;** stay on paved highway. **1.7**

21.7 From 2:00–3:00, Cretaceous sandstones cap low ridges in distance. **0.9**

22.6 Cattleguard. **0.4**

23.0 Cattleguard. Note large playa depression on right. The small, isolated butte at 3:00 is Cartop Butte. **0.7**

23.7 Highway passes through playa. **1.2**

24.9 Drainage system of Pinabetes Creek and tributaries ahead and to right. **1.2**

26.1 Begin descent into Pinabetes Creek. **0.2**

26.3 Intensively bioturbated sandstone and gray siltstone to left of road is Pajarito Formation. **0.9**

27.2 Cross Pinabetes Creek. Green and red claystone and sandstone on right is Morrison Formation. **0.2**

27.4 Mesa Rica Sandstone in gully on left. **2.2**

29.6 Crest of hill. Note the Ogallala Formation on both sides of the road. **0.7**

30.3 Ranch on right. **0.4**

30.7 Mile marker 2. Ghost town at 2:00 is Clapham. Low ridges to left are Romeroville Sandstone. Clapham was named for an early settler, Tom Clapham, who in 1888 built a ranch house with a post office. With an influx of

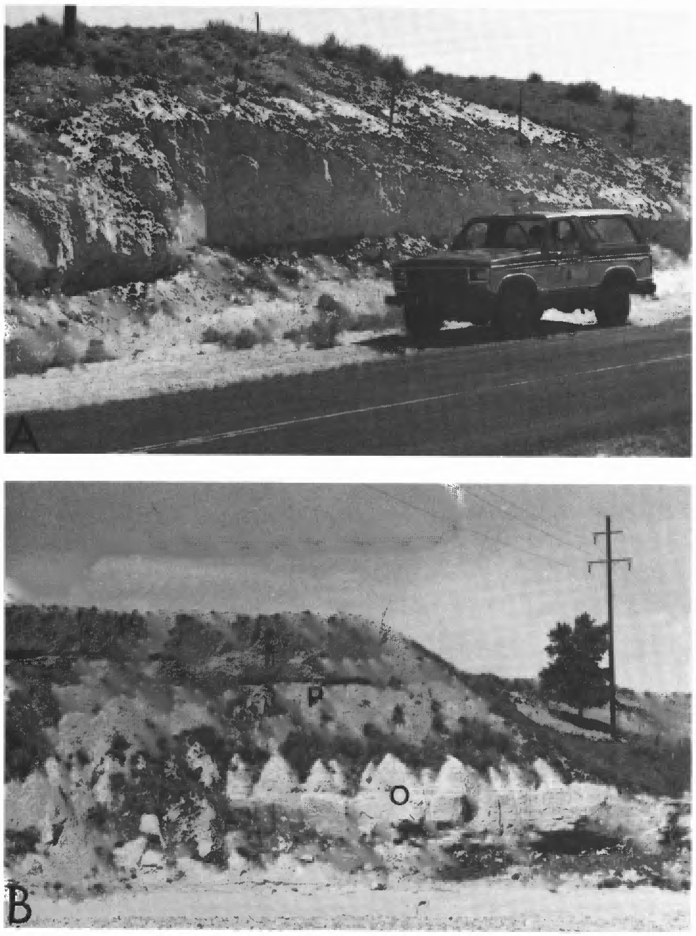


FIGURE 2.5. The Ogallala Formation at mile 14.0 and mile 14.4. A, Ogallala calichified sands on right of NM Highway 562 at mile 14.0. B, Ogallala (O) overlain by Pleistocene gravel, sand, silt and soil (P) in the bank of Carrizo Creek at mile 14.4.

homesteaders a small town developed. The earliest record of a school is 1911, and the following year a Catholic church was constructed. The town, never very large, declined in the 1930's, and by 1940 only 12 residents were recorded. The post office closed in 1955. **0.3**

31.0 Road to right leads to Clapham. **0.5**
31.5 Cattleguard. **0.3**
31.8 Low ridge displaying brown sandstone on right is Mesa Rica Sandstone overlain by gray siltstones of Pajarito Formation. **0.1**
31.9 Romeroville Sandstone on right. **0.1**
32.0 Pajarito Formation on right up to crest of hill which is Romeroville Sandstone (Fig. 2.6). **0.2**
32.2 Mesa Rica Sandstone on right in tributary of Pinabetes Creek. **0.5**
32.7 Cattleguard. Pavement ends and **road forks. Bear right.** Note gravel pit in Ogallala Formation on right and Ogallala calcrete in roadbed. **1.2**
33.9 Road to left; **continue straight. 0.7**
34.6 Lake at 3:00. **0.9**
35.5 Road to left leads to electrical substation. **1.1**
36.6 Cattleguard. Gravel pit in Ogallala Formation to right. **0.7**

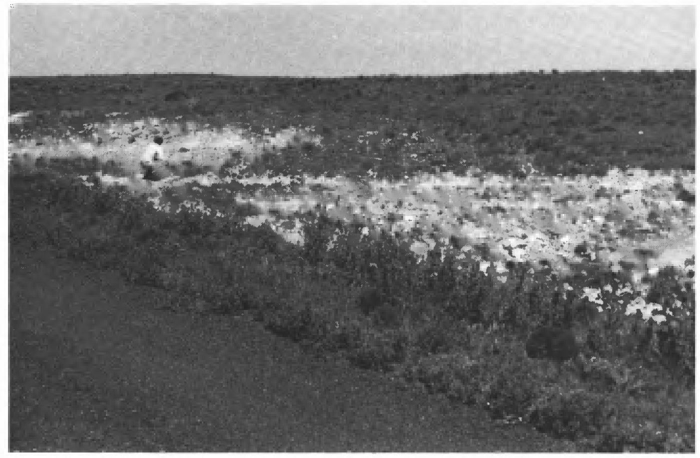


FIGURE 2.6. The Pajarito Formation exposed at mile 32.0.

37.3 **Intersection.** Road to right to Bob Daves ranch. **Continue straight. 0.3**
37.6 Cattleguard. Road descends into Zarcillo Creek. Note escarpment ahead capped by Mesa Rica Sandstone. **0.5**
38.1 Graneros Shale on both sides of road. **0.4**
38.5 Note Romeroville Sandstone on left side of road. **0.1**
38.6 Cattleguard. Cross Zarcillo Creek. Ranch to left. **0.2**
38.8 Stock dam on right is constructed from Graneros Shale. **0.1**
38.9 Pajarito Formation on right overlain by Romeroville Sandstone. **0.5**
39.4 Cattleguard. Enter Blue Front Ranch. **0.4**
39.8 Cross Garcia Creek below stock dam. **0.3**
40.1 Ranch houses to left. Continue straight. **0.3**
40.4 Cross Mesita Creek. **0.1**
40.5 **Intersection; continue straight. 0.4**
40.9 Road curves left. Sandstone capping ridges to right and left is Romeroville Sandstone above slopes of Pajarito Formation. **0.1**
41.0 White, kaolinitic sandstone to left is top of Morrison Formation. **0.1**
41.1 Cattleguard. **0.6**
41.7 **Road forks; stay to right. 0.3**
42.0 Cross tributary of Tramperos Creek. **0.6**
42.6 Top sandstone of Morrison Formation on both sides of road. **0.3**
42.9 Road curves right; Miera at 1:00. **0.3**
43.2 Cattleguard. **0.2**
43.4 Cross tributary of Tramperos Creek. Note top sandstone of Morrison Formation again. **0.7**
44.1 **Road forks; continue straight. 0.6**
44.7 Cross Tramperos Creek. **0.1**
44.8 Enter and leave **Miera** (uninhabited). Miera (Fig. 2.7) was one of the first settlements in northeastern New Mexico. In spring 1873, members of the Miera family of Watrous drove several thousand sheep eastward to search for a well-watered grazing area, and found it along Tramperos Creek. They returned the following year and established a small settlement. Other sheep and cattle ranches soon dotted the Tramperos drainage area, and by the turn of the century and for some years thereafter it was fairly heavily populated (450 people in the

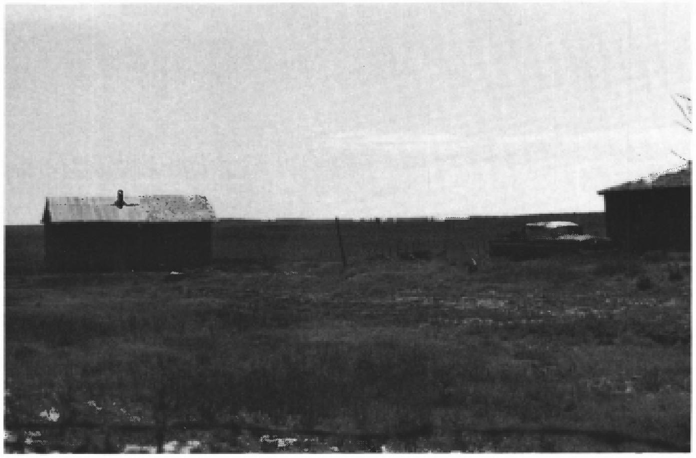


FIGURE 2.7. Miera, New Mexico.

Miera area alone in 1900), with several other small communities in existence. Miera secured a post office (1887–1927), and the village moved to its present location, several mi downstream from its original site, but eventually disappeared. Few people live along the Tramperos now, and the area has reverted to large ranches. **0.4**

45.2 Cattleguard. **Enter Harding County.** Immediately west of this point in the cut bank of Tramperos Creek (SW1/4, sec. 32, T22N, R32E) is the Miera section of Frye et al. (1978, p. 31). Here, 27 ft of Pleistocene (Wisconsinan) sand, silt and clay are exposed and near their base have been radiocarbon dated at 27,500 ± 1,300 B.P. Four species of fossil mollusks—*Hawaiia miniscula, Helicodiscus parallelus, Succinea grosvenori* and *Vallonia parvula*—have been collected just below the radiocarbon-dated horizon (Frye et al., 1978). **0.9**

46.1 **Road forks, bear left. 0.6**

46.7 Abandoned stone buildings and windmill on left. **0.5**

47.2 Crest of hill. Red and green claystones on both sides of road are Morrison Formation. The two sandstones that form a cliff on the ridge crest to the left are Mesa Rica Sandstone. The Canadian Escarpment is visible ahead in the distance. **0.2**

47.4 Cattleguard. **STOP 2** just beyond cattleguard. Here we will examine the Jurassic-Cretaceous boundary (Fig. 2.8). The lower 42.5 m of the section exposed here are fluvial deposits of the Upper Jurassic Morrison Formation. Green and red mudstones that occupy the lowermost 35 m represent clay-sized overbank deposits vertically accreted on a floodplain. The sandstone above these deposits is locally iron-stained and exhibits excellent channel geometry. Typical bedforms are scour marks and planar- and trough-crossbedding. Coloration changes in the sandstone are diagenetic in origin; no major petrologic changes occur within this unit.

A covered, vegetated slope overlies this sandstone. Black, fissile shale can be excavated from near the top of this slope. Microfossils from this sample, and from a sample from a similar, thin unit of shale between the Morrison and Mesa Rica further south, are reported on by Holbrook et al. (1987) in this guidebook. These microfossils indicate a late Albian age and a nearshore marine environment. Lithology and fossils thus indicate

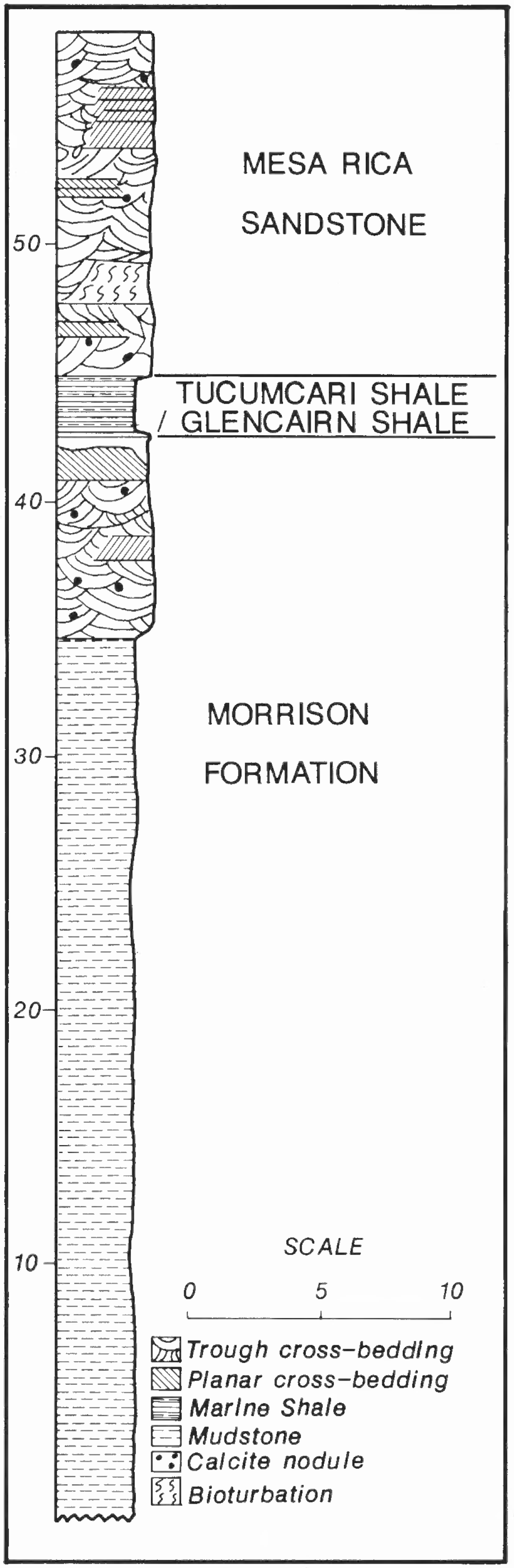


FIGURE 2.8. Measured stratigraphic section at Stop 2.

this unit is equivalent to some portion of the Tucumcari Shale to the south and the Glencairn Formation to the north.

Deltaic sandstones of the Mesa Rica Sandstone occupy the upper 13.7 m of this section. Sedimentary structures in the Mesa Rica include medium-scale trough crossbeds, minor bioturbation, small-scale planar crossbeds and large-scale, sigmoid-shaped planar crossbeds (indicative of large-scale bar migration). The Mesa Rica here most closely resembles the distributary-mouth-bar facies of the Mesa Rica to the south at Mesa Rica, San Miguel County, New Mexico (Kisucky, 1987). Paleocurrent azimuths in the Mesa Rica here indicate paleoflow to the NNW.

Kisucky (1987) argued that a structural high (Bravo dome) influenced Albian deposition in northeastern New Mexico. The virtual absence (greatly thinned) of the Tucumcari Shale and virtual absence of marine influence in the Mesa Rica Sandstone here, near the structural axis of the Bravo dome, support his arguments.

The upper white sandstone of the Morrison Formation in this section is the same unit as white sandstones directly beneath the Mesa Rica Sandstone further south that some workers have included in the Mesa Rica (Trauger et al., 1972). However, other workers have identified this sandstone as the Lytle Sandstone (e.g., Scott, 1970). Our studies indicate that this sandstone can be traced laterally into Morrison mudstones or undisputed Morrison sandstones. Unlike Mesa Rica sandstones, those of the uppermost Morrison contain large amounts of kaolinitic fragments.

After the stop, continue S on NM Highway 562. **0.1**

47.5 Salado Creek on left; note Morrison Formation in roadcuts. **0.7**

48.2 Cross Salado Creek. **0.2**

48.4 Cattleguard. **0.4**

48.8 Cattleguard. Well at 11:00 is 104 ft deep and taps the Entrada Sandstone (water level at 80 ft). **0.3**

49.1 Note Cretaceous sandstones to right on the Canadian escarpment (Fig. 2.9). **0.4**

49.5 Cattleguard. **0.2**

49.7 At 12:00, the Canadian Escarpment is visible; at 10:00–11:00 the Black Hills are the southeasternmost extension of the Clayton basalts. **0.5**

50.2 Cattleguard. **0.6**

50.8 Cattleguard. **0.4**

51.2 Cattleguard. Road bends to right and heads due W on section line. **0.7**

51.9 Cross Ventanas Creek. To the N and NW are escarpments capped by Cretaceous sandstones (Mesa Rica). The deep gullying noticeable in many areas of the field conference is a regional phenomenon. It has been going on throughout the Southwest since the the late 1800's when the regional climate apparently experienced a change from a relatively uniform to an erratic rainfall pattern. Severe droughts now alternate with periods of average-to-above-average rainfall (see Trauger, 1987, in this guidebook). Severe gullying not only occurs during the droughts but immediately follows normal-to-above-normal precipitation before vegetation has had an opportunity to become re-established and stabilize the soil. Hastings and Turner (1966), citing work by Leopold (1951), Schulman (1956) and Sellers (1960), indicate that the climate change that began about 1880 initiated the most severe period of prolonged and intermittent droughts since the 1200's, when similar drought conditions are believed by some to have driven the inhabitants of Mesa Verde, Chaco Canyon and other Indian settlements to the Rio Grande Valley. Only the perfection of the windmill allows human habitants to remain in, and utilize, much of this area today. **1.3**

53.2 Cattleguard. Well on right is 73 ft deep, taps Entrada above Chinle, and water level is 28 ft. **1.1**

54.3 The buff to white sandstone inliers before the escarpment at 2:00–3:00 are Entrada Sandstone. **0.5**

54.8 Cattleguard. **Intersection** with NM Highway 102. **Turn right** and proceed SW. **2.1**

56.9 Enter **Bueyeros** (population 10), a near ghost town. Possibly the oldest settlement in Harding County, Bueyeros dates from 1878. The town was never very large, reaching its height in the 1930's, when it was supported by the dry ice industry. "Bueyeros" is Spanish for "ox-team drivers" and is pronounced "way-err-ose." **0.2**

57.1 Bueyeros post office on right. Church on left (Fig. 2.10). Turn left into church parking lot. **STOP 3.** Note basalt capped Canadian Escarpment to W and flat-topped Entrada inlier to NW. Here, we will discuss the Bueyeros

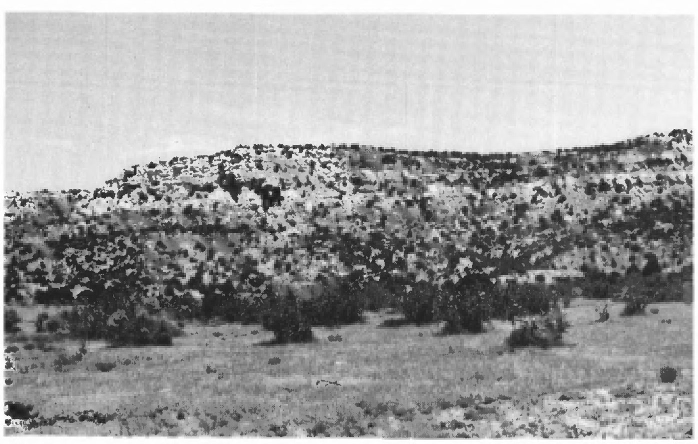


FIGURE 2.9. The Canadian escarpment near mile 49.1. Note white, topmost Morrison Sandstone (M) beneath Cretaceous Mesa Rica Sandstone.

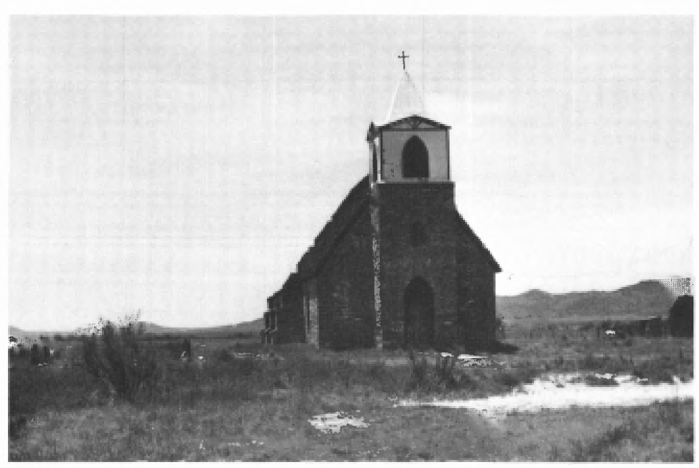


FIGURE 2.10. The church in Bueyeros.

CO_2 field, and, if time allows, tour the CO_2-processing plant near here. CO_2 has been produced from three fields in Union and Harding Counties (Broadhead, 1987, this guidebook). The Bueyeros field produces from Permian and Triassic strata (Fig. 2.11). Estimates of recoverable reserves in the Bueyeros and Bravo dome (NW of here) fields range from 5.3 to 9.8 trillion ft^3 of gas (Johnson, 1983).

After the stop, leave Bueyeros by **continuing W on NM-102. 0.2**

57.3 Cross E fork of Bueyeros Creek. **0.3**

57.6 Cross W fork of Bueyeros Creek and cattleguard. Red and green mottled silts and clays in creek bank on right are Redonda Member of Chinle Formation. **0.3**

57.9 Highway curves left. Mesa north of here displays Jurassic Entrada Sandstone and Bell Ranch Formation. **0.5**

58.4 Cattleguard. **0.6**

59.0 At 2:00, across valley of Ute Creek, note extensive gravel pits developed in terraces of Pleistocene age. **0.4**

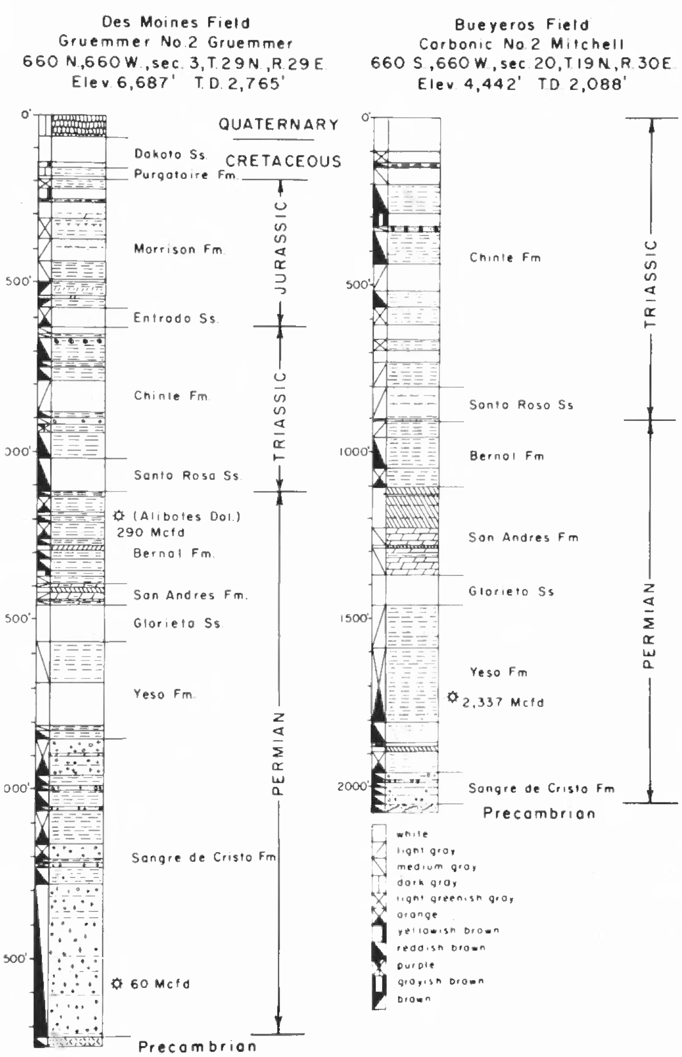


FIGURE 2.11. Representative stratigraphic sections of CO_2 wells in the Des Moines (Union County) and Bueyeros (Harding County) fields (from Foster and Jensen, 1972).

59.4 At 10:30, stock well is 25 ft deep with water at 18 ft tapping alluvium above the Chinle. **0.4**

59.8 Cross Ute Creek. At 9:00, low cuesta of pink-to-white Entrada Sandstone caps ridge in distance. At 2:00, Clayton basalts cap ridge. **0.8**

60.6 Road on left leads to CO_2 wells and pumping plant (Fig. 2.12). The replacement well drilled in 1969 at this location is 2,000 ft deep. **0.8**

61.4 At 3:00–4:00, the slope of Mesa Quitaras exposes green Morrison claystones underneath Clayton basalts. Note entrenchment of Ute Creek in older surface developed prior to late Pleistocene time. **1.5**

62.9 Highway curves left. At 10:00, white Entrada Sandstone is overlain by a ribbed cliff of Bell Ranch Formation. **0.2**

63.1 Cross creek. At 3:00 note green claystones of the Morrison Formation above reddish, ribbed sandstones and siltstones of the Bell Ranch Formation which, in turn, overlie the Entrada Sandstone. **0.3**

63.4 Road to right to Mitchel's Tequesquite Ranch. Note Entrada Sandstone and Bell Ranch Formation at 3:00. Wells about 80 ft deep with water levels at 42 ft tap the Chinle in this area. **0.5**

63.9 Crest of hill reveals Black Hills to left and Canadian Escarpment to right in the distance (reddish bluffs at its base are Entrada Sandstone). **0.4**

64.3 Road curves left. Surface is underlain by Redonda Member of Chinle Formation covered by windblown sand. **2.1**

66.4 At 10:00, note reddish dune sands and greenish clay-

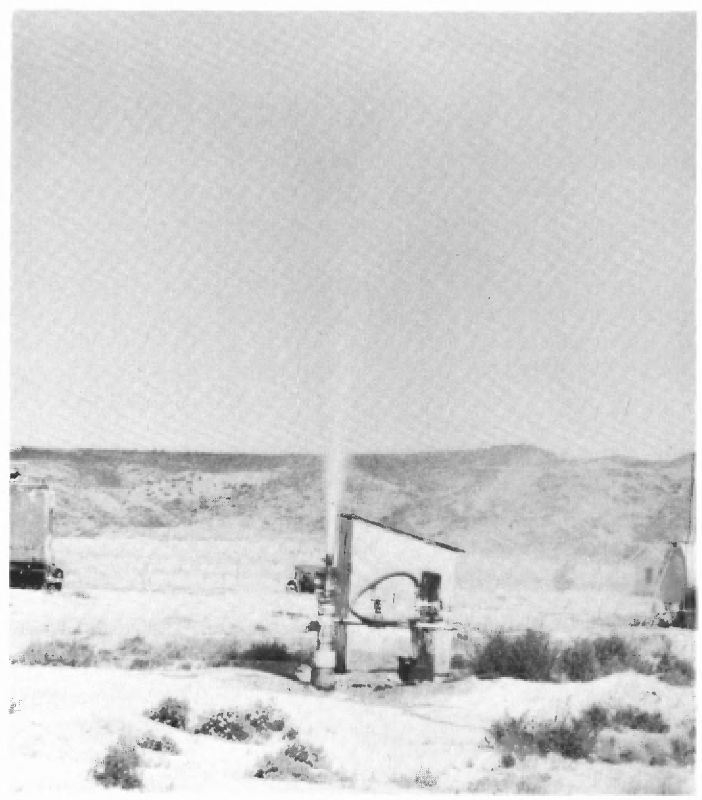


FIGURE 2.12. CO_2 gas well near mile 60.6.

stones of Morrison Formation under basalts. **0.5**

66.9 Road bends to right. On right, wells are about 110 ft deep with water levels at about 66 ft and tap the Entrada Sandstone. These are strong wells yielding 5–10 gpm of good-quality water. **0.8**

67.7 **Junction** with NM Highway 65 at stop sign. **Turn right** and proceed W toward the Canadian Escarpment. Surface for next 2 mi is underlain by Entrada Sandstone. **1.0**

68.7 Crest of hill. At 11:00, buff cliffs at base of Canadian Escarpment are Entrada Sandstone as is the bluff at 10:00. **1.0**

69.7 At 9:00, hill is capped with Morrison Formation above the Entrada Sandstone. **1.0**

70.7 At 11:00, stock well is 69 ft deep, with water level at 44 ft and taps the Redonda Member of the Chinle. Yield is about 0.25–0.5 gpm. **1.9**

72.6 Bridge over Arroyo del Alamo Tequesquite. **0.4**

73.0 At 3:00, stock well is 32 ft deep, with water level at 12 ft and taps alluvium above Chinle. Yield is 2 gpm. **0.6**

73.6 CO_2 storage facility on right. The highway is traversing a plain cut on beds of the uppermost Chinle (Redonda Member). The regional dip is rather uniform to the SE at less than 1°, and thus about the same as the slope of the land surface. Thus, the highway south does not rise or descend in the section appreciably for at least 25 mi. Gentle undulations raise and lower beds locally, but no pronounced structures have been recognized in the valley south to the Canadian River. **1.9**

75.5 Road on right to Tequesquite Ranch. Note crossbedded sandstones of Entrada Sandstone overlain by ribbed Bell Ranch Formation and, then, Morrison Formation. CO_2 wells range from 2 to 5 mi N of this intersection along the road to the Tequesquite Ranch Headquarters.

Thomas E. Mitchel reportedly built the Tequesquite Ranch in the 1880's. Albert K. Mitchel later enlarged the ranch to its present size during the "Dust Bowl" years by buying up many smaller ranches. The CO_2 wells located on the ranch were first developed about 1940–1942. Albert Mitchel's interest in western art led to his acquisition of a large collection of original Remington and Russel paintings and bronzes, mostly purchased in the 1920's and early 1930's, some for a few hundred dollars. The entire collection was housed in the Lovelace Clinic (Albuquerque) after World War II until theft of one of the bronzes in about 1975 resulted in transfer of the collection to the Cowboy Hall of Fame (Oklahoma City). Albert Mitchel, Sr. died in the 1970's. Albert, Jr. died in the crash of his private plane on the ranch in 1984. His son, Terry Mitchel, now manages the ranch. **0.3**

75.8 Low hill at 10:00 is Redonda Member of Chinle capped with gravel of probable middle-early late Pleistocene age. If that age estimate is correct, then lowering of the valley some 100 ft below the level of the gravel occurred during late Pleistocene and Holocene time. **0.3**

76.1 **Junction** with NM Highway 39. **Turn right** and proceed west to climb David Hill. For the next 13.9 mi we will cover part of the second-day road log for the 1985 NMGS Fall Field Conference (Lucas et al., 1985) and the first-day road log for the 1972 NMGS Fall Field Conference (Trauger et al., 1972). **0.1**

76.2 Colluvial wedge of Morrison Formation on right side of highway. **0.2**

76.4 On left, stock tank on the flat receives water piped from a spring in the ravine. The spring issues from the base of the Entrada Sandstone which is underlain by impermeable red beds of the Redonda Member of the Chinle. **0.1**

76.5 At 9:00–10:00 the Jurassic section at David Hill is well exposed (Fig. 2.13). In ascending David Hill, the highway climbs a great landslide mass nearly 1 mi across. Watch for typical landslide features such as closed depressions, rotated bedding and incorporated masses of overlying rock. **0.2**

76.7 Note Morrison Formation on left of highway. **0.3**

77.0 At 12:00–1:00 green claystones of the Morrison Formation are relatively undisturbed part of a landslide and are overlain by brown sandstones of the Mesa Rica Sandstone. **0.2**

77.2 Note red claystones of Morrison Formation on right. **0.2**

77.4 Cliffs at 12:00 are Mesa Rica Sandstone. **0.3**

77.7 On left of highway white sandstone with graffiti is Morrison overlain by colluvium. Brown sandstones above colluvium are Mesa Rica. **0.3**

78.0 On both sides of highway are interbedded sandstones and shales of the Pajarito Formation. Lucas et al. (1985, p. 24) erroneously assigned them to the Tucumcari Shale. **0.5**

78.5 Note Ogallala Formation (no more than 20 ft thick) on both sides of highway. **0.2**

78.7 Highway reaches top of Canadian Escarpment. We are now on the Raton section of the High Plains (Clayton Upland of some authors). The surface of the plateau here slopes about 2° per mi toward the SE. Except along its margins, where deeply incised canyons work headward, the relief generally is less than 30 ft between major drainages which commonly are separated by distances of 3 to 5 mi. Dinosaur footprints recently discovered just S of this point are described in the accompanying mini-paper. **0.1**

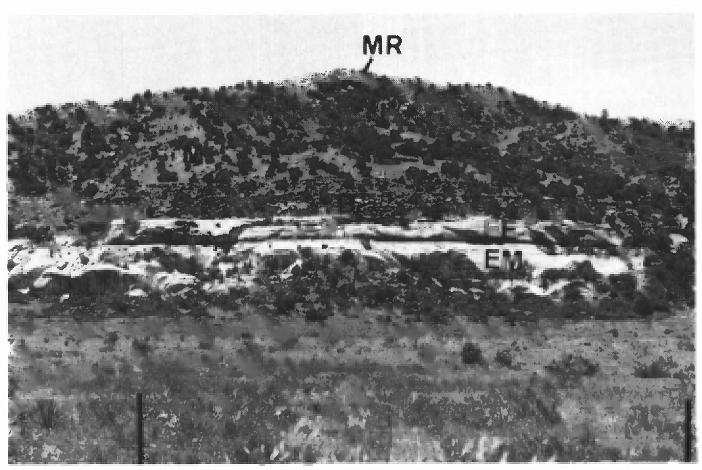


FIGURE 2.13. The Jurassic section of David Hill from mile 76.5. The Entrada Sandstone is divided here by a topographic notch into its main body (EM) and overlying Exeter Member (EE). Interbedded sandstones and siltstones of the Bell Ranch Formation (B) overlie the Entrada, and are overlain by much colluviated claystone-dominated strata of the Morrison Formation (M). The Cretaceous Mesa Rica Sandstone (MR) overlies the Morrison.

DINOSAUR FOOTPRINTS FROM THE CRETACEOUS PAJARITO FORMATION, HARDING COUNTY, NEW MEXICO

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INTRODUCTION

Dinosaur footprints were first reported from the Cretaceous of northeastern New Mexico by Gillette and Thomas (1983). These footprints are located in the uppermost Mesa Rica Sandstone and lower Pajarito Formation at Clayton Lake, Union County (Gillette and Thomas, 1983, 1985; Gillette et al., 1985; Thomas and Gillette, 1985; Lucas et al., 1986). Here, we report another occurrence of dinosaur footprints in the Cretaceous of northeastern New Mexico at Mosquero Creek, Harding County. Terminology of dinosaur ichnology used here follows Leonardi (1987).

GEOLOGICAL CONTEXT

The dinosaur footprints at Mosquero Creek are on the point of the escarpment south of the creek, 6.8 km (4.25 mi) west of NM Highway 39 in the SW1/4 NE1/4 SW1/4, sec. 23, T17N, R29E. On this point, 9.4 m of the Mesa Rica Sandstone underlie 2.1 m of light brownish gray silty shale that we identify as the basal unit of the Pajarito Formation. The sandstone above the silty shale exposes the dinosaur footprints over an area of 557 m^2 (6,000 ft^2) (Fig. 2.14A) and is overlain by gray carbonaceous shale. This sandstone is 30 cm of grayish orange to yellowish brown, fine- to medium-grained, subangular to rounded and moderately well-sorted quartzarenite. Its lower 20 cm preserve sinous- and straight-crested ripples, low angle trough crossbeds, horizontal laminae and tool marks. The upper 10 cm of the footprint-bearing sandstone is extensively bioturbated by both the dinosaur footprints and numerous, small, smooth-walled horizontal tubes. Paleocurrent azimuths from the ripples, troughs and tool marks indicate paleoflow toward N20°W–N50°E for the footprint-bearing sandstone.

The Pajarito Formation represents the delta plain that was associated with the distributary and deltaic system of the underlying Mesa Rica Sandstone (e.g., Mateer, 1985). In the Mosquero Creek area, the Mesa Rica consists of tidally-influenced channel, distributary channel and distributary mouth-bar deposits. Although regional paleoslope of the Mesa Rica was toward the southeast (Gage and Asquith, 1977), paleocurrent azimuths of the Mesa Rica at Mosquero Creek are bimodal, NW and SE. This evidence of tidal influence is also seen in the footprint-bearing sandstone of the overlying Pajarito Formation which flowed NW, against regional paleoslope. Geometry and sedimentary structures of this sandstone suggest it represents a small, tidally influenced channel within an interdistributary area of the delta plain. It is likely that the dinosaur footprints were impressed into this sandbody during a brief period of subaerial exposure.

DINOSAUR FOOTPRINTS

One hundred fourteen footprints are preserved at Mosquero Creek. These footprints represent separate trackways of 31 individuals. The footprints are of one morphology, but can be separated into two size classes:

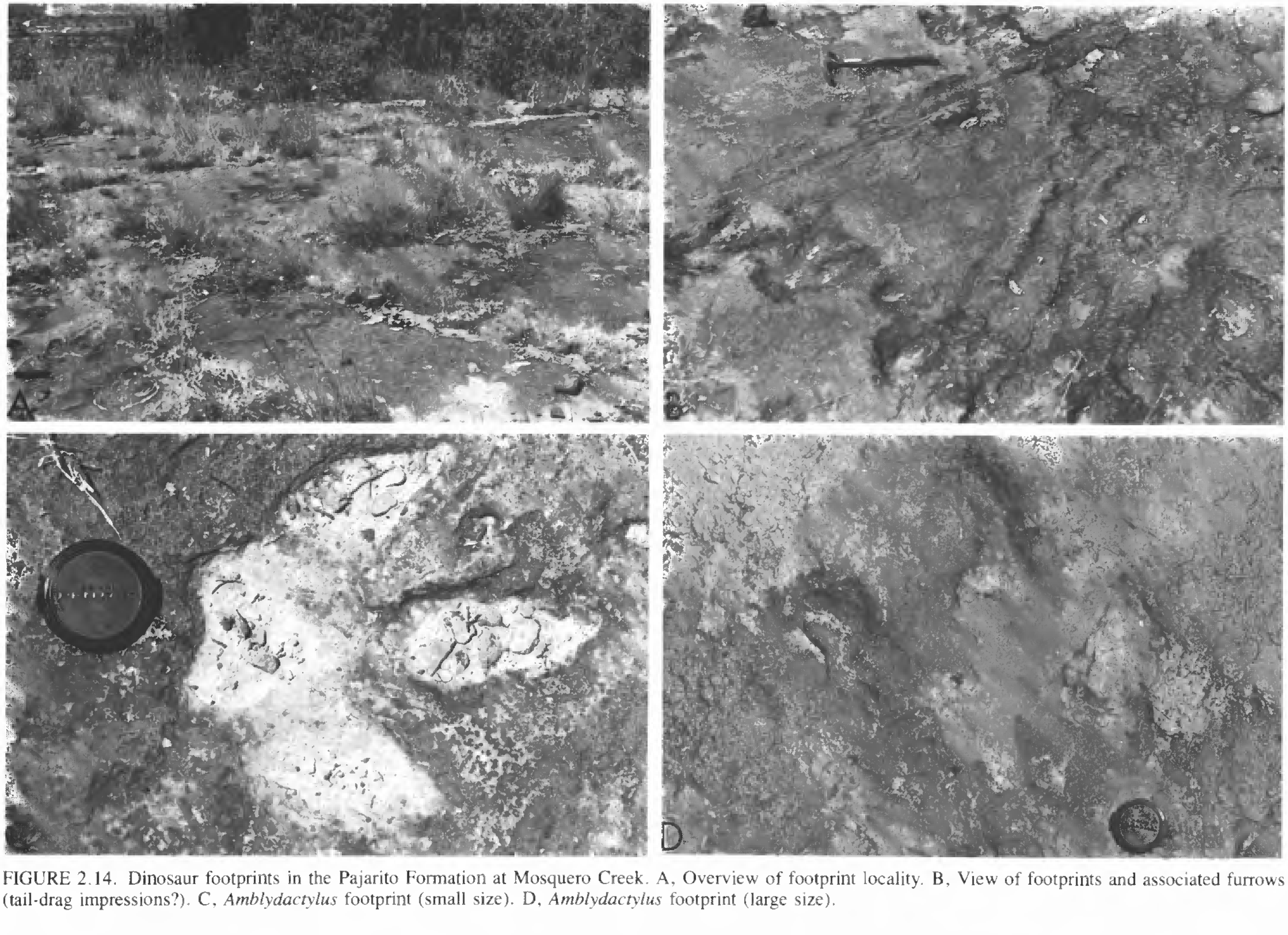

FIGURE 2.14. Dinosaur footprints in the Pajarito Formation at Mosquero Creek. A, Overview of footprint locality. B, View of footprints and associated furrows (tail-drag impressions?). C, *Amblydactylus* footprint (small size). D, *Amblydactylus* footprint (large size).

1. A small class of footprints has maximum lengths of 20–28 cm (Fig. 2.14C). These footprints encompass the trackways of 27 individuals, 24 of which walked toward N10°W–N40°W (with paleoflow) and three of which walked toward S40°E.

2. A large class of footprints has a maximum length of 30–43 cm (Fig. 2.14D). These footprints encompass the trackways of four individuals, all of which walked toward S50°E.

All of the footprints are tridactyl pedal impressions of bipedal dinosaurs. The best preserved footprints (e.g., Fig. 2.14C) display the impressions of large, fleshy digital pads and a more deeply impressed, large metatarsal-phalangeal pad that produced a clear, bilobed "heel" impression. The total divarication of digits II and IV is about 75°.

Closest resemblance of these footprints is with the ichnogenus *Amblydactylus*, putative hadrosaurid dinosaur footprints best known from the Lower Cretaceous of British Columbia, Canada (Sternberg, 1932; Currie and Sarjeant, 1979; Currie, 1983). The principal difference between the Canadian and New Mexican footprints is that the Canadian footprints preserve better the impression of interdigital webbing. However, this difference may reflect substratum differences between the Canadian and New Mexican trackways; a firmer substratum probably would less well preserve the relatively unloaded impression of interdigital webbing. Therefore, we refer the New Mexican footprints to the ichnogenus *Amblydactylus*, footprints of an ornithopod, probably hadrosaurid, dinosaur.

Three long furrows are associated with the footprints at Mosquero Creek (Fig. 2.14B). These furrows have a longitudinal ridge that divides them into two concave-upward grooves. They are not clearly associated with a trackway, although they are in the midst of many footprints. They may represent tail drags, although we are uncertain of an identification. Tail drags and *Amblydactylus* footprints have been reported in the Pajarito Formation at Clayton Lake (Gillette and Thomas, 1985).

DISCUSSION

The occurrence of *Amblydactylus* footprints in the lower part of the Pajarito Formation at Mosquero Creek supports identification by Lucas et al. (1986) of the principal dinosaur-footprint-bearing strata at Clayton Lake as Pajarito Formation. *Amblydactylus* and *Amblydactylus*-like footprints have a broad stratigraphic range from Early (Valanginian) through Late (Maestrichtian) Cretaceous (Langston, 1960; Haubold, 1971). Therefore, the presence of *Amblydactylus* in the Pajarito Formation does not aid in the refinement of its age, which is probably late Albian (Lucas et al., 1986).

The presence of so many trackways headed in the same direction at Mosquero Creek is consistent with the notion that some ornithopod dinosaurs were gregarious (Ostrom, 1972; Currie, 1983). However, it is impossible to confirm that all the trackways were impressed at the same instant and not over a period of hours, days or weeks.

Finally, it is possible to calculate the speed of one of the dinosaurs (small class) that left its trackway at Mosquero Creek. This trackway consists of twelve footprints over a distance of 7.6 m, and footprint lengths are 0.24 m. Using the equation of Alexander (1976), height at hip $\cong$ footprint length $\div$ 0.25, the height at the hip of this dinosaur was approximately .96 m. Kool's (1981) estimate of speed based on a least squares regression analysis is: speed = 1.4 (stride length [m]/hip height [m]) – 0.27. Therefore, the speed of the New Mexican dinosaur was 1.4(1.27/.96) – 0.27, or 1.6 m/s or 5.8 km/hr (3.48 mi/hr). This is well within the range of speeds for *Amblydactylus* from Canada reported by Kool (1981, table 1) and Currie (1983, table 1).

78.8 At 2:00 in the far distance, basalt-covered hills of the Clayton volcanic field are visible. **0.2**

79.0 At 3:00 note old stone dug-out house. The original room was sunk about 2 ft below the land surface. The water-well here is 100 ft deep and water level is at 75 ft, tapping the Ogallala and Dakota Group. **0.8**

79.8 Windmill on right pumps about 1 gpm (in a strong wind) from the Ogallala Formation. **2.3**

82.1 Road enters highway from right. To left, note drainage of Mosquero Creek in distance. **1.0**

83.1 Road curves left. Dirt road to right leads 3 mi to Black Lake, one of the larger sinks in this area (3.5 mi N-S by 3 mi E-W, closure about 100 ft). A well, producing about 50 gpm from "sand and black clay," is located at the south end of the lake. **0.3**

83.4 At 9:00–10:00 the Canadian Escarpment is visible in the distance. **0.8**

84.2 Highway dips in creek valley revealing some yellow Romeroville Sandstone. The surface for the next few mi is underlain by the Ogallala Formation which averages about 60 ft thick in this area. Because the Ogallala here is thin, overlies permeable sandstone and is topographically high, it is a poor aquifer. **1.2**

85.4 Road curves left. **0.5**

85.9 Road curves right and crosses a small sinkhole. **Mosquero** (population 197; elevation 5,560 ft) is the seat of Harding County. The town originated as a railroad siding along the Dawson Railroad, which was constructed to carry coal from the Dawson mines near Raton to the railhead at Tucumcari. An enterprising teacher, Benjamin Brown, formed the Mosquero Land Company, advertised in Kansas newspapers for homesteaders and platted a townsite in 1908. Brown erected a hotel, and the railroad built a depot. A post office and, for a short time, a newspaper followed as homesteaders arrived. Partly because of lobbying by Mosquero town officials, the New Mexico Legislature created Harding County in 1921, with Mosquero the county seat, and the community incorporated as a town the following year. Mosquero thrived during the 1920's and 1930's due to the production of dry ice from the Bravo Dome CO_2 field, and had a population of nearly 750 by 1940. Dry farming was also a major industry until the 1940's, but the area now depends mainly on livestock raising. **0.6**

86.5 Leave Mosquero. At 10:00 in the distance the snow-capped Sangre de Cristo Mountains are visible. **0.6**

87.1 Roadside table and historical marker for the Goodnight-Loving Trail, a route for the great Texas cattle drives of the late 1800's, on right. **2.9**

90.0 **Junction** with NM Highway 65. **Proceed to the right** on NM-39 NW to Roy. The fork to the left continues the first-day road log of the 1985 NMGS Conference (Lucas et al., 1985). **0.8**

90.8 Note Ogallala Formation in ditch on left. The surface of the plateau from here to N of Roy is dotted with many small, round-to-oval-shaped depressions, commonly called sinks. A few are as much as 1 mi or more across in their long dimension. These sinks frequently contain small ponds during the summer rainy season. Some are reputed by long-time residents to have contained water the year-round in the period 1900–1920. Chicosa Lake, NE of Roy, is one such sink that contains water the year-round. It was an important stop on the Goodnight-Loving Trail in the 1880's.

The origin of the sinkholes is attributed to solution and collapse in deep-lying formations of carbonate rocks. The maximum relief of Kansas Valley sink, one of the larger sinks on the plateau, is as much as 130 ft in an area where the Ogallala Formation is believed not to exceed 50 ft in thickness. The sinkholes are assumed to have developed after the deposition of the Ogallala Formation as the Ogallala does not thicken in the vicinity of the sinks. At Church Lake, about 3 mi SW of Solano, the Ogallala Formation is not more than 20 ft thick, and the Romeroville Sandstone crops out around the western side of the sink which is about 1 mi wide by 1.5 mi long with 40 ft of closure.

Drainage channels are relatively well defined over most of the plateau surface but are not deeply incised anywhere in the immediate area. Many relatively short, shallow drainages terminate in the sinks just described. **0.2**

91.0 Between Mosquero and Roy the highway traverses the approximate axis of a broad anticlinal structure trending northwest. The edge of the plateau marked by the western margin of Ogallala outcrop is just west of the highway along most of the route, and continues S for about 10 mi N of Roy to the vicinity of Mills. **1.2**

92.2 Windmill well on right is 161 ft deep and taps the Ogallala Formation in an old, buried channel. Static water level is about 120 ft below the land surface. **0.2**

92.4 To right of highway, just inside of the fence line are two wells that also tap an Ogallala buried channel. They are 208 and 214 ft deep and yield about 20–30 gpm. The wells are in an elongate, shallow sink that may define part of the buried channel. **0.7**

93.1 On left note CO_2 compressor plant. For many years this plant processed gas from the Bueyeros CO_2 field but is no longer operating. The highway here is trending up the "dip" of the High Plains surface and rising about 40 ft per mi. The altitude at Mosquero is 5,588 ft and at Roy, 5,892 ft; the distance between the two is about 18 mi, for an average grade of 17 ft per mi. **1.3**

94.4 Enter **Solano.** Solano may have been named for St. Francis Solano, a Spanish Franciscan, who evangelized in South America (especially Peru). It was also a surname of the family of Antonio Solano y Castro, who was married in Santa Fe in 1763. The townsite of Solano was established in 1907 as a station on the Dawson Railroad, and served homesteaders who were moving to this area. A plant to manufacture dry ice was established in the late 1930's, and the population reached about 70, but is less than half that now. Solano post office on left. **0.2**

94.6 Leave Solano. **0.3**

94.9 Windmill at right is over old railroad well that bottomed in the Chinle at 926 ft. **1.5**

96.4 Road to right leads to Solano cemetery. **0.6**

97.0 Dirt road to right leads 1.5 mi to Roy municipal well-field in La Pompa draw. In this area, the draw trends SE and seems to follow approximately the course of an old, buried channel. SE is the trend of most buried channels in this area. **2.0**

99.0 At 9:00 the windmill in the shallow valley taps the Dakota Group. **0.6**

99.6 At 12:00 in distance Las Mesas de Conjelon are part of the Ocate volcanic field. **0.4**

100.0 The windmill well at 3:00 taps Ogallala water at 78 ft.. **1.8**

101.8 Road curves right, crossing Weisdorfer Draw, "headwaters" of the recharge area for the Roy well-field, 3.5 mi to the E (see Trauger et al., 1987, this guidebook). **0.1**

101.9 Windmill well at 3:00 is 119 ft deep and taps Ogallala water at 91 ft. **1.2**

103.1 Highway skirts the western edge of a small sinkhole. This sinkhole will contain water for 4 to 6 months in a year of normal precipitation. **0.7**

103.8 Note Mills Canyon Historical Marker (Fig. 2.15). Enter **Roy** (population 381; the largest town in Harding County). Roy was first settled around 1900 at a location about 2 mi west of its present site by Frank and William Roy. The town moved to the tracks of the Dawson Railroad a few years later, and grew as the major service center for homesteaders moving into the area. A disastrous fire destroyed much of Roy in 1916, but the town rebuilt and prospered until the 1940's with successful dryland farming and the production of dry ice from the Bravo dome CO_2 field. The town's population reached a high of more than 1,100 in 1940, but like other communities in Harding County, has decreased considerably since then. Mills Canyon Historical Marker refers to a spectacular horticultural enterprise of the 1880's and 1890's along 12 mi of the Canadian River. There, the Orchard Ranch cultivated vegetable gardens and several thousand fruit trees until a flood destroyed the area in 1904. **0.7**

104.5 **Junction** with NM-120 at flashing stoplight. **Turn left** to proceed W on NM-120. Early water wells in the vicinity of Roy were of uncertain dependability and always of low productivity. A few shallow wells (50–100 ft deep) found small amounts of water in the Ogallala Formation. Many wells were finished in the Dakota Group aquifer. A well about 0.1 mi SE of this junction was 440 ft deep and developed 2.5 gpm. **0.2**

104.7 **Pavement curves to left;** continue on it. **0.3**

105.0 Leave Roy. Note rodeo grounds on right. **0.3**

105.3 At 2:00, radio towers sit on rimrock of Ogallala Formation which is about 100 ft thick at this point and highly calichified. Gravel pits have been opened on the points of the rimrock to obtain road material. Here, the Ogallala unconformably overlies the Greenhorn Formation which, in turn, overlies the Graneros Shale. Both of these units are thin here. **0.3**

105.6 Crest of hill. At 1:00 across the valley note basalt-covered Las Mesas de Conjelon. Road will now descend into the Canadian River Valley. We have just left the anticlinal axis and now travel toward a synclinal axis

FIGURE 2.15. Mills Canyon Historical Marker at mile 103.8.

that has determined the course of the Canadian River (Fig. 2.16). **1.1**

106.7 Cattleguard. Highway is now on a bench of the Romeroville Sandstone. **0.3**

107.0 Stock pond on right in gulch bounded by Romeroville Sandstone which is dense and relatively impermeable here. **1.2**

108.2 Cattleguard. **0.8**

109.0 Note brown sandstones of the Romeroville in valley at 3:00. Road is on slope that dips 2–3°W. **0.3**

109.3 Cattleguard. Shallow valley to right is headlands of Beaver Canyon. **0.5**

109.8 Ray Ranch road on right. **1.2**

111.0 At 1:00, note the broad, shallow synclinal structure that stretches from Roy, about 7 mi E of the Canadian River, to the Cuernudo Hills about 6 mi W of the river. The surface of the plain drops from an elevation of 5,935 ft at mile 105.6 to 5,460 ft near mile 113.3. The river is entrenched about 550 ft below the rimrock on the E side and 500 ft on the W side. From the western rimrock, the surface rises from an altitude of 5,405 ft to about 6,250 ft. Thus, the syncline is slightly asymmetrical, the western limb being steeper. **0.8**

111.8 Stock pond on right and Romeroville Sandstone. **0.6**

112.4 For next 0.3 mi, note Romeroville Sandstone on both sides of road and in cliffs to right. **0.4**

112.8 Gray siltstones and sandstones to left and right of highway for next 0.2 mi are Pajarito Formation. A basal conglomerate of the Romeroville overlies the Pajarito here. **0.5**

113.3 Mesa Rica Sandstone on right. **0.1**

113.4 Cattleguard **0.1**

113.5 Green claystones of Morrison Formation are overlain by Mesa Rica Sandstone to right. **0.1**

113.6 Highway is now on red and green claystones of the Morrison Formation. The Early Cretaceous (late Albian)

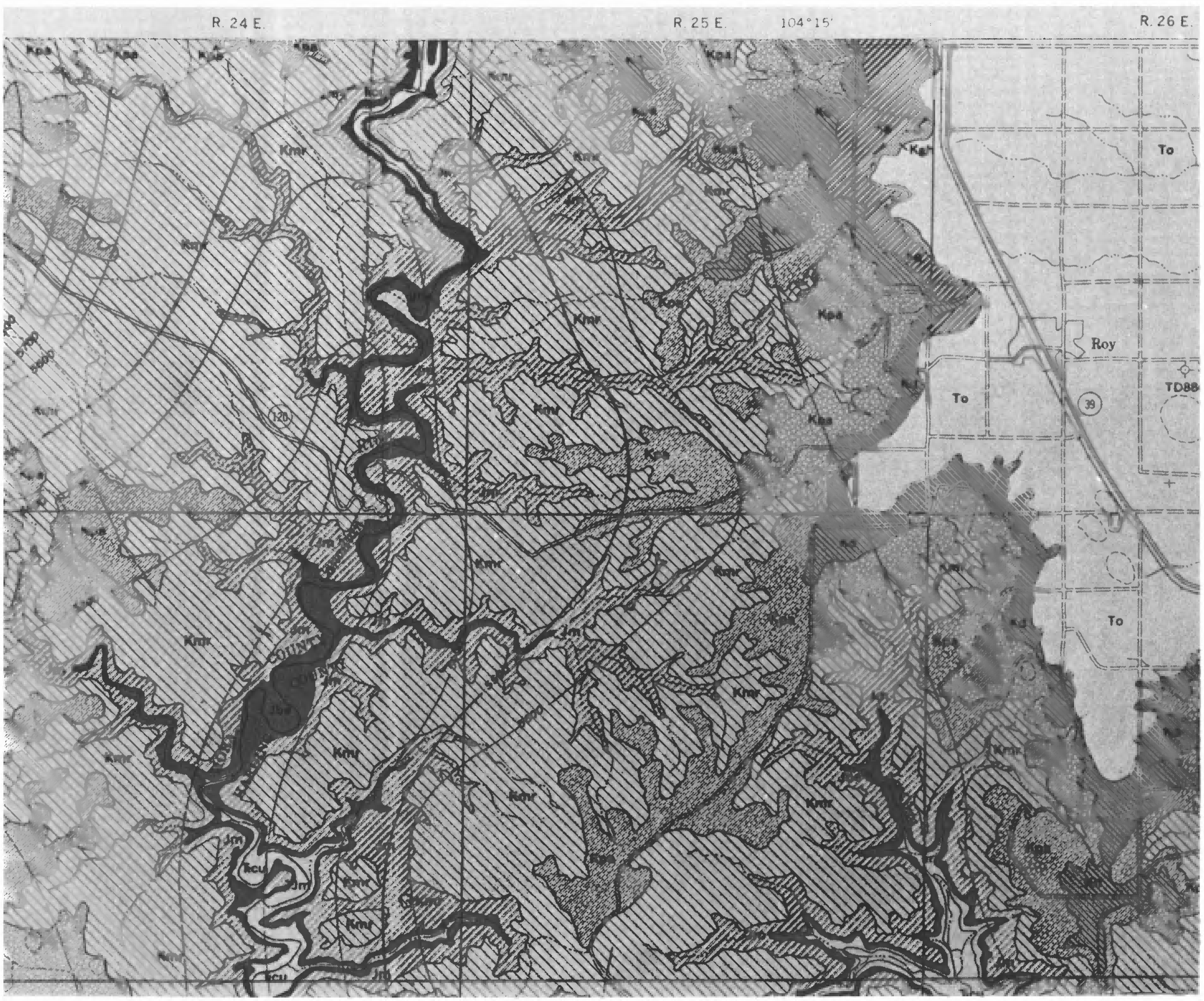

FIGURE 2.16. Geological map of the Mills Canyon area (from Wanek, 1962). Map units are: Trcu = Chinle Formation, Redonda Member; Jbe = Entrada and Bell Ranch formations; Jm = Morrison Formation; Kmr = Mesa Rica Sandstone; Kpa = Pajarito Formation; Kd = "Dakota" Sandstone (Romeroville Sandstone of this guidebook); Kg = Graneros Shale; Kgh = Greenhorn Formation; and To = Ogallala Formation.

Tucumcari Shale, present between the Morrison and Mesa Rica in Quay and parts of Harding and Guadalupe Counties, is absent here. **0.5**

114.1 The Morrison sandstones on the left are part of a medial sandstone complex of the Morrison Formation found throughout much of east-central New Mexico. **0.3**

114.4 Brick-red and green claystones of the basal part of the Morrison Formation on left. These beds are present at the base of the Morrison throughout northeastern New Mexico, but are sometimes mistaken for Chinle by drillers. **0.1**

114.5 **Dirt road to right. Turn right. STOP 4.** Here, one of the most well-exposed sections of the Jurassic strata in northeastern New Mexico can be examined (Fig. 2.17). Particularly prominent here is the Bell Ranch Formation of Griggs and Read (1959), interbedded siltstones and gypsiferous sandstones that lie between the Entrada and Morrison. The Bell Ranch is lithologically similar to and occupies the same stratigraphic interval as the Wanakah Formation on the Colorado Plateau. The Morrison section above it features a medial sandstone complex that is a persistent unit throughout parts of San Miguel, Harding, Guadalupe and Quay Counties (e.g., Wanek, 1962; Trauger and Bushman, 1964; Mankin, 1972; Lucas et al., 1985). **After the stop, turn around and retrace route 9.5 mi to Roy. 9.5**

124.0 Enter Roy. **0.6**

124.6 **Stop sign** at junction of NM-39 and NM-120 (First and Richlieu Streets). **Continue straight** (E) on NM-120 toward Clayton. **0.3**

124.9 Pavement curves left. **0.5**

125.4 On the right, note the homestead log-dwelling of William and Matilda Roy in Matilda Roy Draw (built about 1900). Bernardo Esquibel, younger brother of Matilda, and in his 90's, still lives in the house. **0.3**

125.7 Roy cemetery on right. **0.2**

125.9 Cross John Snyder Draw (Fig. 2.18). Test water wells for Roy were drilled about 0.5 mi E of here in 1958 to a depth of 919 ft and developed 10 gpm. **0.2**

126.1 Abandoned house and windmill on right. Well is 148 ft deep, water level is 67 ft, and well taps Ogallala. **0.9**

127.0 Cross Ivey Draw. Windmill wells on either side are about 100 ft deep. Water level is about 50 ft deep when measured and reportedly fluctuates seasonally and climatically. These wells tap the Ogallala, and the recharge boundary is about 1.5 mi to the W. **0.8**

127.8 Windmill well on right is 63 ft deep, its water level is 52 ft deep and it taps the Ogallala. **1.2**

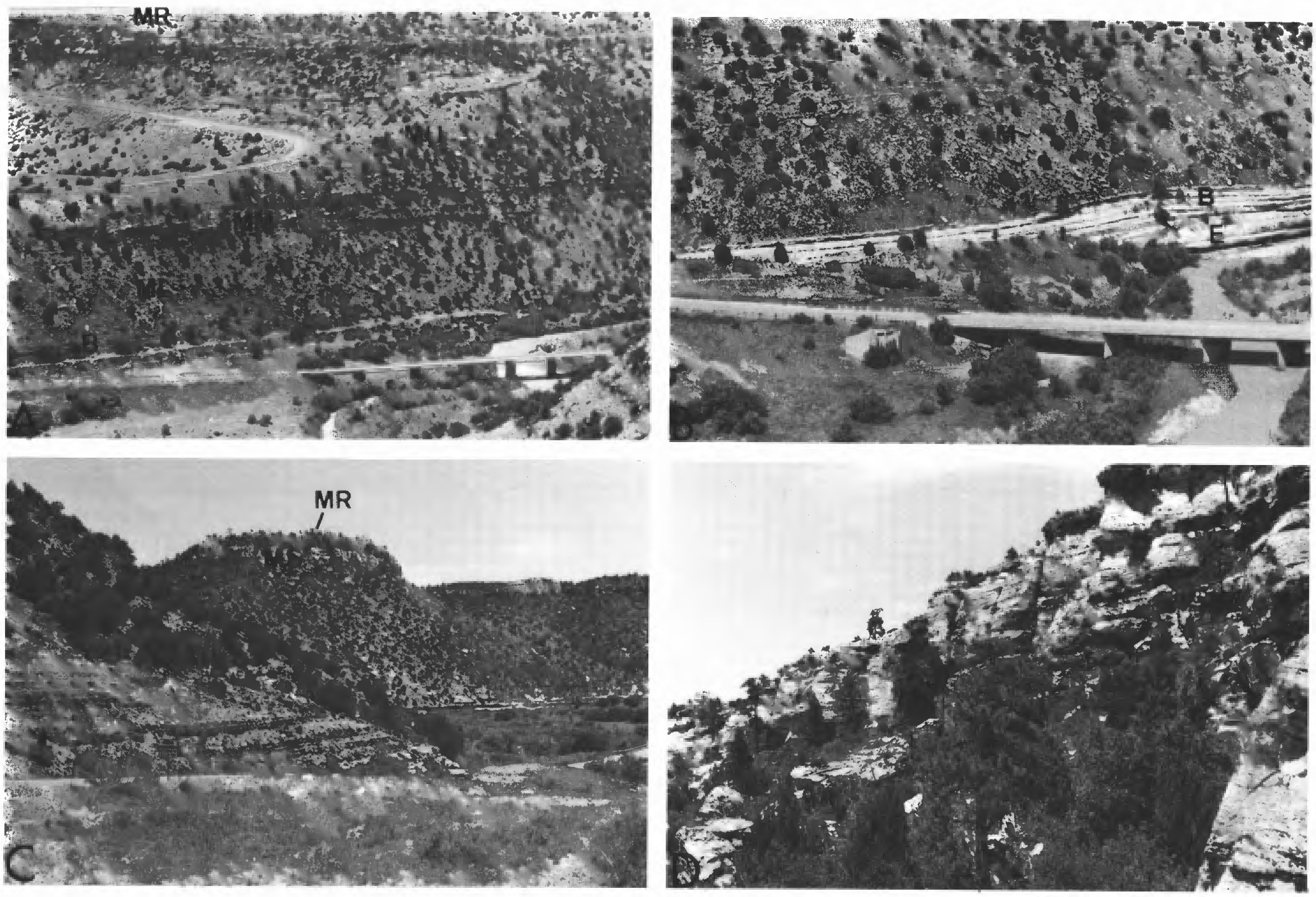

FIGURE 2.17. Jurassic and Cretaceous strata exposed at Stop 4. A, View of bridge over Canadian River and Bell Ranch (B), tripartite Morrison (ML = lower Morrison, MM = medial Morrison sand complex, MU = upper Morrison) and Mesa Rica (MR) formations. B, View of bridge over Canadian River and Entrada (E), Bell Ranch (B) and Morrison (M) formations. C, View of lower Morrison in foreground and, in the background, uppermost white sandstone of Morrison (MS) overlain by Mesa Rica Sandstone (MR). D, Mesa Rica Sandstone on western rim of Mills Canyon.

FIGURE 2.18. Partially buried buildings attest to the amount of wind-blown sediment deposited during the "Dust Bowl" years. These buildings are near John Snyder Draw, 2 mi E of mile 126.2.

FIGURE 2.19. Big Chicosa Lake from near mile 131.9.

129.0 Road curves left. On left, note Gibson Lake (bed), a sink with a closure of about 25–30 ft. **0.2**

129.2 Windmill well on right is 200 ft deep, has a water level of 124 ft and taps the Ogallala. At 12:00–2:00, note volcanic cones in the distance. **0.4**

129.6 Road makes sweeping curve to right. **0.4**

130.0 Note small sink on right with about 15 ft of closure. On the left, note Big Chicosa Lake (bed). This large, sinkhole complex is about 2.5 mi across. The closure is about 40 ft. In about 1960, the village of Roy drilled test wells to depths of about 60 ft in the floor of the sink. Water reportedly was found in sand and gravel from 22 to 57 ft, and the static water level was 16 ft below the land surface. A pump test produced about 115 gpm. However, the water contained fluoride concentrations in excess of those permitted for public supply, and the wells could not be developed for city supply (Trauger et al., 1986, pp. 73–74). **0.7**

130.7 Steep pipe on left marks site of test well, but no records can be found. **0.4**

131.1 Road curves left. **0.8**

131.9 Entrance to Chicosa Lake State Park to left. Frye et al. (1978) reported six molluscan species from Wisconsinan sediments just east of Chicosa Lake (center, sec. 11, T21N, R26E). The lake here (Fig. 2.19) is a permanent body, and is a water-table lake in a sinkhole that is part of the Big Chicosa Lake (bed) depression. The floor of the sink containing the permanent lake is about 30–35 ft lower than the floor of Big Chicosa Lake (bed). The water level varies seasonally and climatically. The lake was an important stopping point on the Goodnight-Loving Trail in the 1880's. **0.8**

132.7 Gravel pit in Ogallala Formation at 3:00. Road descends into Kansas Valley "Lake," a large circular depression some 5 mi in diameter. The lake has an outlet on the SE side. Closure is about 60 ft. At overflow level the lake has a surface area of about 10 mi^2. **1.1**

133.8 Cross Kansas Valley. **0.2**

134.0 Windmill well at 9:00 is 38 ft deep, water level is 23 ft (taps the Ogallala), and the water smells of hydrogen sulfide and tastes bad. **0.7**

134.7 Playa lake on left in shallow sink. **1.5**

136.2 Mile marker 86. Note Ogallala Formation to left and right of highway. **1.7**

137.9 Ranch on right. **1.1**

139.0 Foundation of house and Ogallala Formation on right. In this area the Ogallala Formation is about 100 ft thick but generally yields no water, being topographically high and drained. **0.9**

139.9 Begin left turn in highway. **0.5**

140.4 From 2:00–4:00 note Ogallala Formation and Clayton basalts on ridge beyond. Enter Carrizo Creek Valley, excavated in the Ogallala. **0.6**

141.0 Cattleguard at curve in highway. **0.2**

141.2 Note buff sands and calcrete of Ogallala Formation to right and left. **0.5**

141.7 Road curves right. **0.7**

142.4 Note ranch building at 2:00. The water well here is 34 ft deep, and water level (in Ogallala) is at 33 ft. **0.2**

142.6 At 9:00 Cerro de la Cruz, a volcanic cone of the Clayton basalt field, is visible in distance. **0.6**

143.2 Ogallala Formation in roadcuts on both sides of highway and Clayton basalts visible ahead. **0.2**

143.4 Cattleguard. At 2:00, Clayton basalt caps Ogallala outlier. Road curves left. **0.1**

143.5 Cross Carrizo Creek and begin ascent onto Clayton basalt-capped surface. **0.5**

144.0 Note Ogallala Formation under Clayton basalts along highway. **1.5**

145.5 The basalts in this area are about 100 ft thick. **1.1**

146.6 At 9:00, just to the N, are three small sinkholes as well as numerous others on the basaltic plain. These collapse structures are mostly, if not entirely, of Pleistocene to Holocene age. **0.4**

147.0 About 1 mi to the S, El Toro Spring issues from the base of basalt flows overlying the Ogallala Formation. Carrizo Creek, a tributary of Tequesquite Creek, has cut through the Dakota Group and deeply incised the underlying Morrison Formation. About 2 mi S, Carrizo Canyon is trenched about 400 ft below the surface on which we are traveling. Several distinct benches have been developed at intermediate levels, the most pronounced being at the top of the Romeroville Sandstone. **0.5**

147.5 Highway makes sharp turn to left. At about 10:00, the volcanic crater has a well preserved central spine (Fig. 2.20). The following mini-paper discusses the age of the basalts in this area. **3.2**

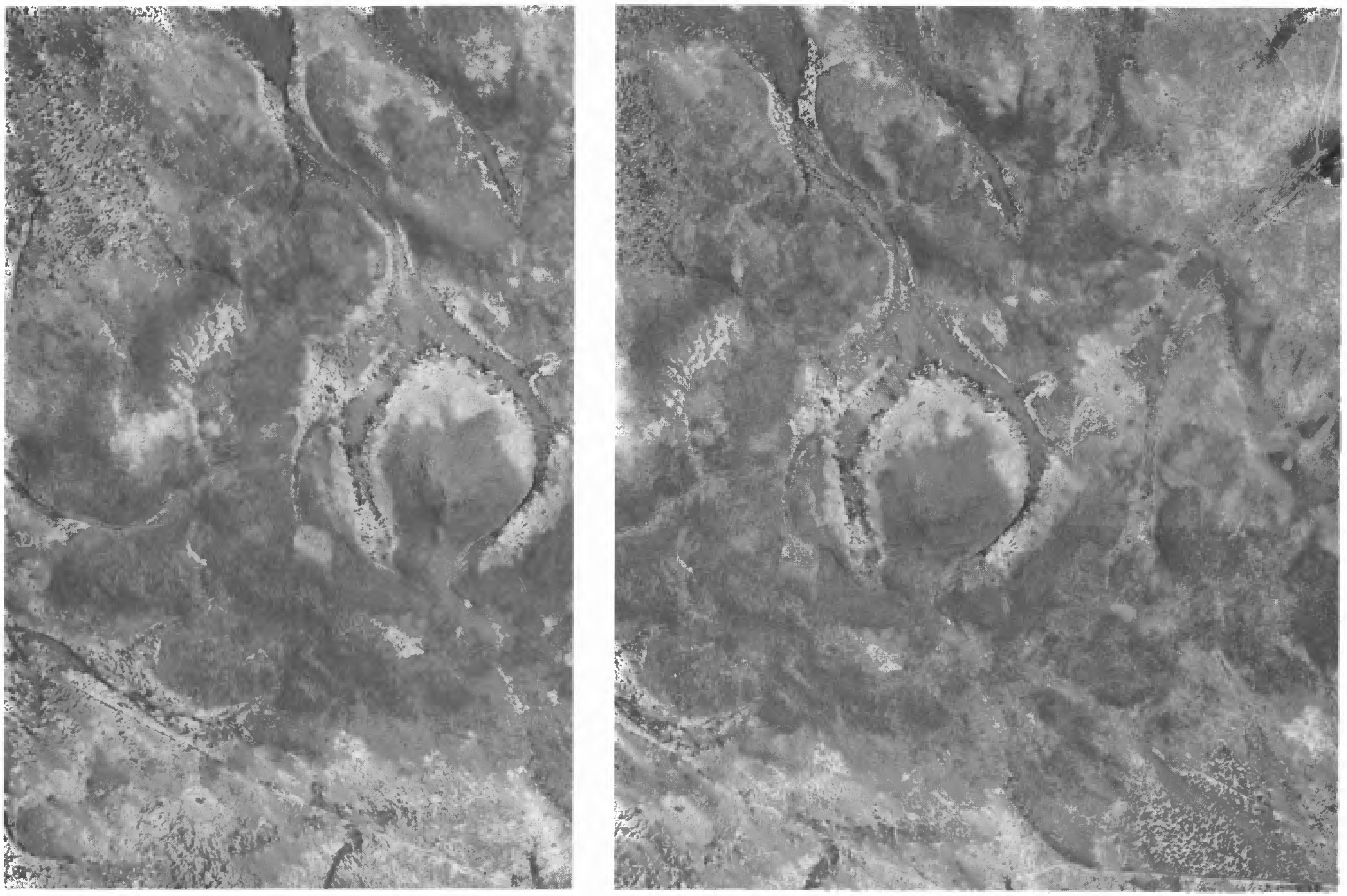

FIGURE 2.20. Aerial stereophotographs of volcanic crater just NW of Yates. Note well-preserved central spine.

K-AR DATES ON A BASALT FLOW AND A VENT PLUG IN NORTH-CENTRAL HARDING COUNTY, NEW MEXICO

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The samples discussed below were collected specifically for radiometric age determinations to help establish the age of a sequence of basalt flows in Harding County and its relationship to the Raton, Clayton and Capulin basalts described and mapped in Union and Colfax Counties by Baldwin and Muehlberger (1959) and earlier by Lee (1922), Collins (1949) and Wood et al. (1953), none of whom had the benefit of K-Ar dates. The details of the radiometric analyses of the samples were published (Trauger, 1973, p. 7) and will not be repeated here. The samples were dated by R. E. Denison, Mobil Research and Development Corporation.

The flows overlie fluviatile deposits of Pliocene age (considered to be part of the Ogallala Formation) and rocks of Cretaceous age, and are mostly covered by colluvium, soil and stabilized dune sand. They are best exposed as scattered outcrops in shallow drainageways on the plain and in the rim-rock bordering Carrizo Creek. The dozen or so vents in Harding County rise as conspicuous prominences above the otherwise rather featureless surface of the High Plains outlier upon which they and the flows rest. The surface of the High Plains outlier stands about 800 ft above the valley floor of Ute Creek at Bueyeros.

In earlier reports, the various sequences of flows were assigned ages ranging from early Pleistocene to late Holocene. The early Pleistocene ages were predicated on the assumption that the underlying beds of the Ogallala Formation represented latest Pliocene time. Baldwin and Muehlberger (1959, p. 79) recognized that the older basalts might have been erupted during the Pliocene and so changed the Pliocene-Pleistocene boundary to include the first- and second-period flows of Lee (Raton basalt of Collins, 1949 and Wood et al., 1953). These earlier workers had, on the basis of certain inferences, arbitrarily placed the boundary at the beginning of volcanic activity. Baldwin and Muehlberger's change in the boundary was based on the inferred correlation of algal limestones overlying the basalts with algal limestones of Pliocene age in Kansas.

The high topographic position of the flow sampled (NW$^{1}/_{4}$ NE$^{1}/_{4}$, sec. 15, T21N, R29E), considered with the fact that it locally overlies beds of Pliocene (Ogallala) age, suggested that it was of early Pleistocene age and therefore probably equivalent to the Raton and Clayton basalts. The 3.4 ± 1.0 m.y. age means that the basalt could be of late Pliocene age and therefore is equivalent to either the first- or second-period flows of Lee and Mertie (or Raton and Clayton basalts of later reports). If it is of late Pliocene age, and equivalent to the second-period flows, it would mean that the first-period flows could extend well back into Pliocene time, perhaps even farther back than imagined by Baldwin and Muehlberger. Obviously, more K-Ar dates are needed from the various sequences of flows to get a good fix on their ages.

The 1.2 ± 1.0 m.y. age of the sample from the central spine in the vent crater in the NW$^{1}/_{4}$, sec. 14, T22N, R28E, 2 mi NW of Yates, came as something of a surprise as it was thought this vent was the source of the flow. The age determined would make it a correlative of the third-period basalt flows of Lee (1922), or the "Clayton" basalt of Collins (1949) and Wood et al. (1953), and the Folsom area flows of Baldwin and Muehlberger (1959). It supports Baldwin and Muehlberger's observation (1959, p. 78) "that volcanic activity was essentially continuous in the region but that the locus of volcanism shifted, so that in any particular area the volcanism appears to have been periodic."

A relevant observation resulting from the determination of a late Pliocene or early Pleistocene age for the flows in the area southeast of Yates is that the broad deep valley of Ute Creek, from the vicinity of Bueyeros to the Canadian River, had to have been cut to its present width and depth during early and middle Pleistocene time. Gravel-capped hills and fossil-bearing lake deposits of probable late-Pleistocene age are found in the valley of Ute Creek south from Bueyeros. A mammoth skull and associated bones reportedly were found in alluvial deposits in the entrenched valley of La Cinta Creek, southwest of Solano, and about 850 ft below the Ogallala surface. Some of the gravel-capped hills lie almost at the foot of the Canadian Escarpment, and about 700 ft below the Pliocene-age High Plains surface.

150.7 Dip in highway reveals Clayton basalts. **1.2**
151.9 At 3:00 are two irrigation wells about 115 ft deep. Water level is about 48 ft, and yield is reported to be about 150 gpm from Clayton basalt above the Ogallala. **0.5**
152.4 Enter **Yates** (Fig. 2.21), a former small settlement now composed of a single ranch. Don Carlos Hills on horizon to N. Highway now makes sharp turn to right. **0.3**
152.7 Leave Yates. **0.4**
153.1 Cross Alamocito Creek. **0.2**
153.3 Highway makes sharp turn to left. **0.8**
154.1 Mile marker 104. Small basalt hill at 2:00 is Aragon Hill. About 1.5 mi SE of Aragon Hill, a tributary of Ute Creek has cut through the basalt exposing Graneros Shale above the Romeroville Sandstone. **1.4**
155.5 At 9:00, water well at ranch buildings is 87 ft deep, has a water level of 76 ft and obtains water at the base of basalt overlying Ogallala. **0.3**
155.8 Note large sink with small playa; closure is about 25 ft. **0.5**
156.3 Playa on right. **0.2**
156.5 Leave Harding County. **Enter Union County. 3.0**
159.5 Sharp right turn in highway. Begin descent into Ute Creek. **1.5**
161.0 Cross bridge. Note Romeroville Sandstone to left in creek. **0.3**
161.3 To left along Ute Creek are good outcrops of Pajarito Formation overlain by Romeroville Sandstone (Fig. 2.22). **0.1**
161.4 Cross Ute Creek. **1.5**
162.9 Road curves left. Miller Ranch on right. Don Carlos Hills to N. **2.5**

FIGURE 2.22. Pajarito Formation overlain by Romeroville Sandstone in Ute Creek near mile 161.3.

165.4 Playa on right. **1.3**
166.7 Cross pipeline. **0.7**
167.4 Note large playa beyond house foundation to right. **1.2**
168.6 **Junction** of NM-120 and US-56. **Turn right** and proceed E on US-56 toward Clayton. The Don Carlos Hills (Fig. 2.23), visible for several mi north of the highway, are a group of 14 aligned volcanic vents surrounded by basalt flows that cover an area of more than 75 mi^2. Baldwin and Muehlberger (1959) distinguished several groups of flows. The oldest forms the central platform of the hills but is exposed only in a limited area near the center. This basalt is characterized by conspicuous augite phenocrysts and intensely altered olivine, overlies Ogallala sands and gravels and stands several hundred ft above the surrounding land, suggesting that it is correlative with the Raton basalt to the north. Younger basalts, similar to the main Clayton basalt, cover most of the area around the vents and overlie the oldest (Raton) flow. Individual tongues extend southward down Ute Creek to the west and across the Pasamonte lowlands to the east. The youngest flows immediately surround some of the vent and are fine-grained, with unaltered augite and olivine. **0.7**
169.3 Note two flows of the Clayton basalts on the S side of the Don Carlos Hills at 9:00. **2.9**

FIGURE 2.21. Yates, New Mexico.

FIGURE 2.23. Part of the Don Carlos Hills from mile 168.6.

172.2 Note on left deep playa lake and basalt flows below and in front of the basalt-capped meas. **1.0**

173.2 Wall built of basalt on left; playa (Pasamonte Lake) on right. The Pasamonte flow of Clayton basalt from eastern vents of the Don Carlos Hills is visible to left for the next 3 mi. **1.6**

174.8 Playa on right. **1.7**

176.5 Note Ogallala Formation in roadcut. **0.6**

177.1 Looking N, three basalt cones are visible (from W to E): Chavez Mountain, Tripod Mountain and The Hogback. **1.9**

179.0 **Junction** with NM-120 which goes N to Grenville. **Continue E** on US-56. **1.1**

180.1 Unpaved road to right leads to Pennington. **2.3**

182.4 Descend into drainage of Upper Pinabetes Canyon **1.3**

183.7 Mesa Rica Sandstone to right. Cross NE tributary of Pinabetes Canyon. **0.5**

184.2 Gray siltstones and sandstones of Pajarito Formation on either side of highway. **0.6**

184.8 Mile marker 60. Rabbit Ear Mountain at 10:00. **0.3**

185.1 Pajarito Formation on right. **0.6**

185.7 Ogallala Formation on both sides of highway. **1.0**

186.7 Pajarito Formation on right. **0.1**

186.8 Gravel pit in Ogallala Formation at 3:00. **0.2**

187.0 Brown sandstone at 9:00 in Trabajo Creek is the Mesa Rica Sandstone **2.8**

189.8 Cross Carrizo Creek. The Pajarito Formation is exposed under the bridge and along the banks of the creek (Fig. 2.24). The Carrizo flow of the Clayton basalt is extensively exposed along the N side of the creek. **0.6**

190.4 Second bridge over Carrizo Creek; note Pajarito Formation in creekbed. **0.6**

191.0 Ogallala Formation on both sides of highway. **0.8**

191.8 Ogallala Formation on left is overlain by Clayton basalts. **0.6**

192.4 Crest of hill. Rabbit Ear Mountain at 11:00 in distance. **1.7**

194.1 Crest of hill. Cedar Hills at 2:00–4:00 are composed of Ogallala Formation **2.3**

196.4 Cross tributary of Sand Draw. **2.6**

199.0 Mile marker 74. Here, and for the next 3 mi, the Ogallala Formation is intermittently exposed along the highway. **3.0**

202.0 Clayton at 12:00. **0.8**

202.8 Note dune field to right next 0.2 mi. **1.5**

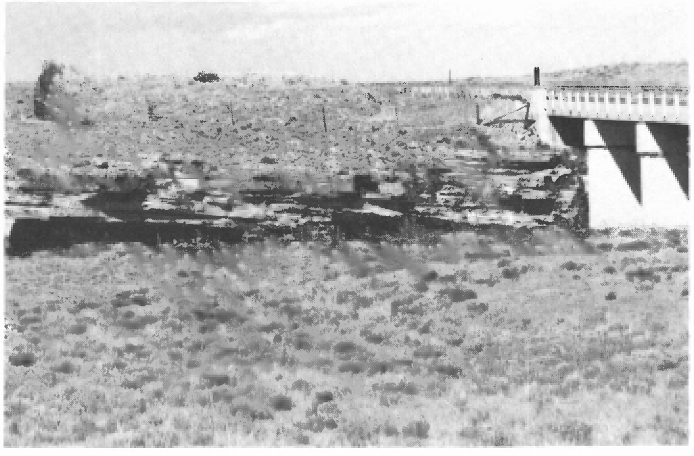

FIGURE 2.24. Exposure of the Pajarito Formation at mile 189.8.

204.3 Cross Perico Creek. Note gray Graneros Shale underneath creek alluvium to right. **2.1**

206.4 Clayton Historical Marker on right. **0.7**

207.1 **Clayton** city limit (population 2,968). Ogallala Formation outcrops on right are overlain by Clayton basalts. We are entering Clayton on Monroe Street which should be followed as it turns into Main Street until reaching the junction with NM-18. Prior to 1887, northeastern New Mexico was unfenced rangeland, with few human inhabitants, but large numbers of free-roaming cattle, sheep and even a few buffalo. The building of a railroad designed to link Denver and Fort Worth brought an influx of people and led to the development of towns such as Clayton, Folsom and Des Moines. One branch of the railroad built southward from Denver into New Mexico through Tollgate Canyon; the other (the Fort Worth and Denver Railroad) built northwestward from Fort Worth. The two branches met a few miles north of Folsom, and the first passenger train traversed the line in March 1888. As the railroad neared, the townsite of Clayton was platted in fall 1887, and a tent town grew up. There were plans to make Clayton a division point on the railroad, as it had a good supply of water from Apache Springs, was on level ground and was about halfway between Trinidad and Amarillo. However, a dispute between the owner of the water supply and the railroad caused the removal of the roundhouse and other equipment to Texline. The new town was named for the son of an ex-senator from Arkansas, Stephen Dorsey. Dorsey had extensive cattle interests in the area, and is perhaps best remembered for the ornate but lonely mansion he built at Chico Springs 57 mi W of Clayton (the mansion is still standing).

Clayton's location on the railroad immediately made it an important shipping point for cattle and sheep. Stockyards, warehouses, saloons and other amenities for the cattle- and sheepmen rapidly proliferated. In addition to local cattle, thousands more were driven north to Clayton each year from as far south as Fort Sumner and Roswell, to be shipped east on the railroad. Wool-buyers from the East gathered in Clayton during shearing time each year; by one account nearly 3 million pounds of wool were shipped annually during the 1890's. Clayton prospered also when it became the county seat shortly after Union County was created in 1893. One of the town's most notable buildings is the Eklund Hotel, constructed in 1892, which is still operating as a restaurant today.

Life was not easy in the early years. A severe blizzard isolated Clayton for two weeks in the winter of 1889, killing thousands of livestock and several people as well. "Black Jack" Ketchum and his gang of train robbers operated in the area for awhile, until Ketchum attempted a solo job near Twin Mountain (between Folsom and Des Moines). He was wounded, captured and hanged in Clayton in April 1901, an event that attracted hundreds of interested spectators. Clayton was also home for awhile to Ernest Thompson Seton, whose story "Lobo, King of Currumpa" was based on a giant wolf that terrorized ranchers northwest of the town for more than five years before it was trapped in 1894. So great was the fear of this animal that the bounty on its head reached $1,000—a tremendous sum of money in those days.

The coming of the railroad also opened the Clayton area to homesteaders, as dryland farming of corn, maize, pinto beans and sorghum proved successful. Many wet years and high prices for agricultural products through the 1920's boosted Clayton's economic base, and by 1930 the town's population had surpassed 2,500. Drought, dust storms and the Depression put an end to Clayton's rapid growth, but unlike other towns in the area, Clayton was large enough to weather the bad times with few lasting ill effects. At first the government bought up thousands of acres of abandoned land, and then in 1939 ranchers began buying up homesteads vacated by farmers, and grazing once again became the dominant economic activity of Union County. In recent years development of the Bravo Dome CO_2 field by AMOCO (see Broadhead, 1987, this guidebook) has been a great stimulus to the economy of Clayton and Union County. **0.6**

207.7 Cross railroad tracks. **0.1**

207.8 **Stop light.** Junction with NM-18 (First Street). **Turn right** and proceed S on First. **0.5**

208.3 Sunset Motel on right. **Turn left** on Locust Street and stop.

End of road log for Second Day.