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SECOND-DAY ROAD LOG, FROM TUCUMCARI TO MESA REDONDA, PYRAMID MOUNTAIN, RAGLAND, AND BLACKWATER DRAW, NEW MEXICO

SPENCER G. LUCAS, ADRIAN P. HUNT, ANDREW B. HECKERT, BARRY S. KUES, and VIRGINIA T. MCLEMORE

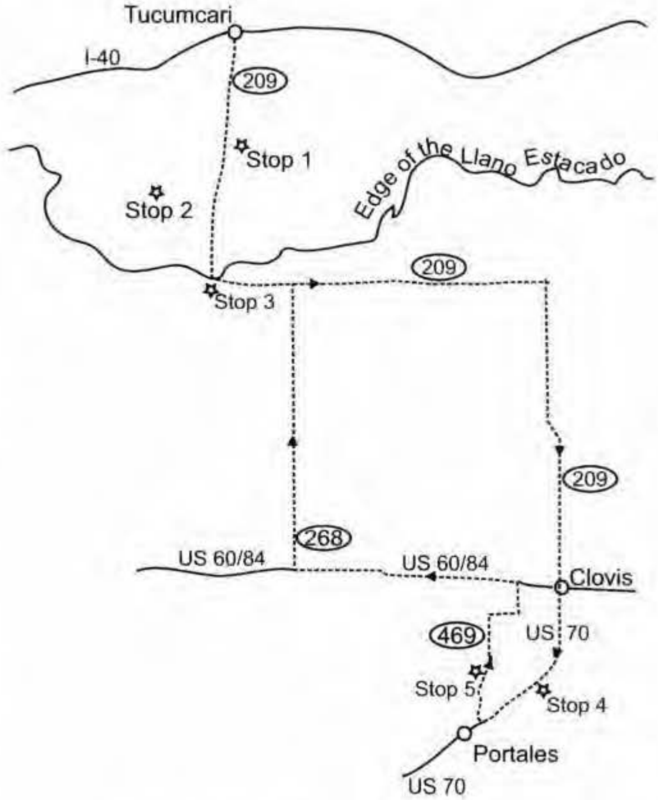
FRIDAY, SEPTEMBER 28, 2001

Assembly point:	Mesalands Dinosaur Museum, 222 East Laughlin, Tucumcari
Departure time:	7:30 AM
Distance:	229.5 miles
Stops:	5

SUMMARY

Today's trip begins by examining Mesozoic strata exposed around erosional outliers of the northern edge of the Llano Estacado in Quay County, New Mexico. STOP 1 at Mesa Redonda is at the type section of the Redonda Formation, the youngest Upper Triassic strata beneath the Llano Estacado. Here, we discuss the base of the Redonda Formation, a possible regional unconformity, and the depositional environment of the formation.

STOP 2 is at Pyramid Mountain, where, in September 1853, Jules Marcou undertook the first detailed scientific observations made by a trained geologist in New Mexico. Here, we examine the Triassic-Cretaceous section. STOP 3 at Ragland affords an excellent exposure of the Neogene Ogallala Formation. STOPS 4 and 5 are at the Blackwater Draw Museum and Blackwater Locality No. 1, respectively. Here, we examine the type Clovis locality, its stratigraphy, deposition and dating.



Mileage

0.0 Assemble at the Mesalands Dinosaur Museum, 222 East Laughlin, Tucumcari. **Turn left out of museum parking lot onto S. Adams and immediately turn left (west) onto East Laughlin. 0.1**

0.1 Stop sign. **Turn left** (south) on First and proceed south. **0.1**

0.2 Go straight through traffic light with Tucumcari Boulevard and continue south out of town. **1.4**

1.6 Pass under bridge of Interstate 40. Tucumcari Mountain at 10:00. **Continue south (straight) on NM-209. 0.2**

1.8 Brown sandstone on both sides of the road is Lower Cretaceous Mesa Rica Sandstone; road surface is on Upper Jurassic Brushy Basin Member of the Morrison Formation.

The Mesa Rica Sandstone that is close to road level forms the highest cliff on Tucumcari Mountain about 1.3 mi to the E, so there is obviously a significant structure between the road and Tucumcari Mountain. Dobrovolny et al. (1946) mapped a westward dip of 11° in the Bull Canyon Formation about 1 mi east of the highway. Therefore, the structure must be northerly in strike and located about a third of the way from the western boundary of sec. 36 T11N, R30E. Dobrovolny et al. (1946) mapped no fault, so by implication they must have assumed that this was the limb of a monocline. Trauger et al. (1972) noted a "sharp flexure" here that dropped the Chinle Group about 500 ft. This structure continues under the city of Tucumcari because there are outcrops of the Morrison Formation, not mapped by Dobrovolny et al. (1946), in the western portion of the city near Tucumcari Elementary School, whereas the Chinle Group is exposed in the eastern area near Tucumcari Lake. Given the gentle dips of all folds in the area (Dobrovolny et al., 1946) and the presence of the southwest-northeast trending Bonita fault southeast of Tucumcari (Stearns, 1972), it is most likely that the structure on the western side of Tucumcari Mountain is a fault. **0.4**

2.2 Historical Marker on left for the Llano Estacado; good view of western side of Tucumcari Mountain. **0.3**

2.5 Green mudrocks on right are Upper Jurassic Brushy Basin Member of the Morrison Formation. The majority of the Morrison Formation in this area consists of green claystone with minor channel-form sandstone. In Quay County, dinosaur bones are relatively common in the Morrison, but the vast majority are isolated and fragmentary. **0.3**

2.8 Bulldog Mesa at 10:00. Most of the mesa is red beds of the upper part of the Chinle Group (Bull Canyon and Redonda formations); cliff of Middle Jurassic Entrada Sandstone is visible near its top. These units are distinctly lower on Bulldog Mesa than on either Tucumcari Mountain or Mesa Redonda as a result of a large Laramide fault that underlies Plaza Larga Creek between Bulldog and Redonda mesas (Dolliver, 1985). On right, sandstones of the Lower Cretaceous Mesa Rica Formation cap cuestas in the Tucumcari structural zone. **1.4**

4.2 Crest hill, Lower Cretaceous Mesa Rica Sandstone faulted on right of road. Mesa Redonda visible from 10:00-11:00. **1.2**

5.4 Vegetation-covered Quaternary dunes(?) visible at 3:00. **0.6**

6.0 Edge of Llano Estacado in distance at 9:00-10:00. Hills at 2:30 are Lower Cretaceous Tucumcari Formation and Mesa Rica Sandstone over Upper Jurassic Morrison Formation. The latter has yielded bones of sauropod dinosaurs in this area. **1.3**

7.3 Crest low ridge. From 1:00 to 2:00 are Saddleback Mesa, Circle S Mesa, Pyramid Mountain and edge of Mesa Quemado. **1.2**

8.5 Road to Briscoe Ranch to right. Mesa to right is informally called Section 29 Mesa and includes Triassic through Cretaceous strata of the Redonda through Mesa Rica formations. **1.0**

9.5 Quay County Road QR-54 to right, which skirts the southern edge of Mesa Quemado. Kues and Kietzke (1985) provided a log of this road, to reach Pyramid Mountain, but the road has since been abandoned and is now impassible. **0.3**

9.8 Cross tributary of Plaza Larga Creek. **0.7**

10.5 **Turn left** on unpaved QR-53, stop to open gate; now entering private land owned by Larry and Virginia Wright. **0.5**

11.0 Road forks—**turn right on lesser road** and cross cattleguard and gate. **0.4**

11.4 Good overview of Mesa Redonda ahead. Stratigraphic succession is (in ascending order) Upper Triassic Chinle Group, Middle Jurassic Entrada Sandstone, Upper Jurassic Morrison Formation, Lower Cretaceous Tucumcari Formation and Lower Cretaceous Mesa Rica Sandstone. **1.6**

13.0 Type section of the Upper Triassic Redonda Formation (Chinle Group) overlain by Middle Jurassic Entrada Sandstone at 12:00. **0.3**

13.3 **Stay left** as road enters from the right. **0.1**

13.4 **STOP 1.** This is the type section of the Redonda Formation (Fig. 2.1) and also affords us a broad overview of many of the erosional outliers of the northern edge of the Llano Estacado in Quay County (Fig. 2.2). The Redonda Formation was named by Dobrovolny et al. (1946) for the widespread and distinctive lithosome that represents the youngest Triassic strata of the Tucumcari basin in east-central New Mexico (Lucas and Hunt, 1989). The Redonda is as much as 92 m thick and rests unconformably on the early to middle Norian Bull Canyon Formation. The top of the formation is an erosional unconformity at the base of the overlying Middle Jurassic Entrada Sandstone or the Neogene Ogallala Formation.

Here, the Redonda Formation consists of mudstone, fine-grained sandstone, limestone, siltstone and a single bed of conglomerate (Fig. 2.1). The laterally perisistent beds of sandstone and siltstone, the moderate reddish brown color and the general lack of smecitic mudstone distinguish the Redonda Formation from the underlying Upper Triassic Bull Canyon Formation. The base of the Redonda Formation here is a thin (~1-6 m), mottled, burrowed-to-structureless, calcareous siltstone that is laterally continuous for several mi. Hester (1988) interpreted this to represent lacustrine precipitation of carbonate mud and subsequent bioturbation of a soupy, unconsolidated substrate. Overlying Redonda strata are massive mudstones and sandstones that form laterally continuous repetitive beds, followed by ripple-laminated micrites. The upper interval of the formation is mostly massive mudstones and sandstones.

The Redonda Formation pertains to the youngest of three Chinle Group depositional sequences,

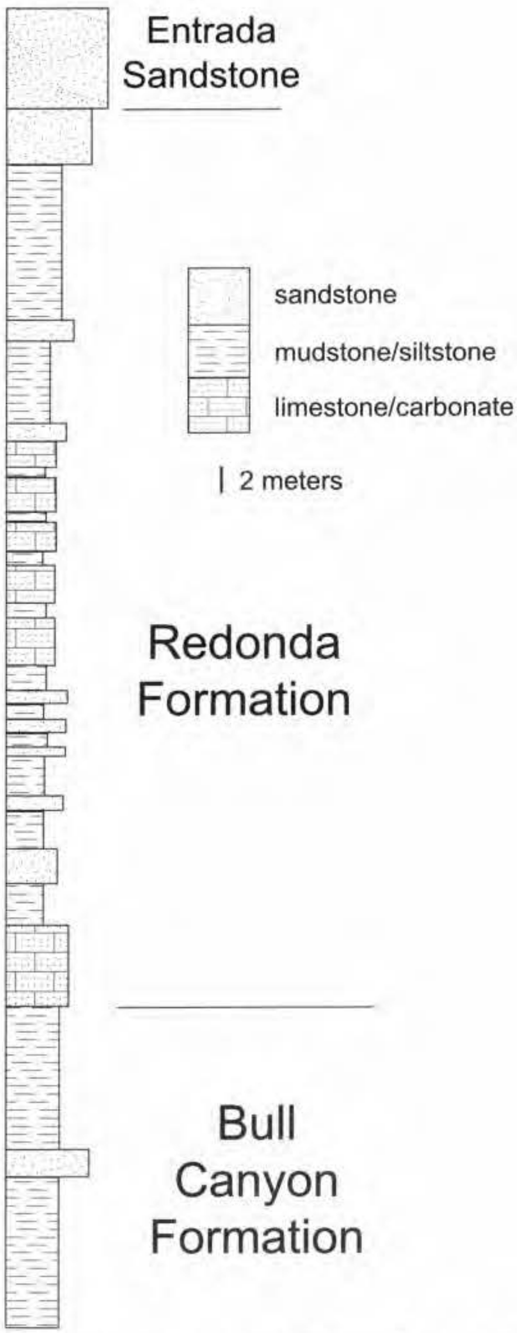


FIGURE 2.1. Stratigraphic section of the Upper Triassic Redonda Formation (type section) at Stop 1 (modified from Hester, 1988).

the late Norian-Rhaetian Rock Point sequence of Lucas (1991, 1993), and is correlative with the Rock Point Formation on the Colorado Plateau, the Bell Springs Formation in Wyoming, and the Travesser and Sloan Canyon formations in the Dry Cimarron Valley of northeastern New Mexico, westernmost Oklahoma and southeastern Colorado. Most of these units contain significant, laterally extensive lacustrine deposits whose origin is related to fluctuating intrabasinal hydrologic gradients punctuated by seasonal, monsoonal paleoclimatic circulation patterns (cf. Dubiel et al., 1991).

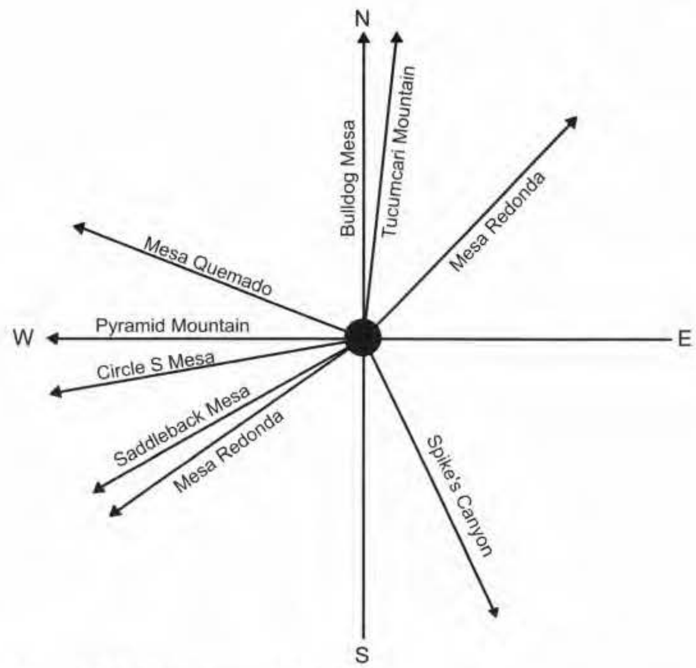


FIGURE 2.2. Vista diagram at Stop 1.

Long term climatic influence over Redonda Formation sedimentation and facies distribution may be indicated by the laterally-continuous, cyclic, ripple-laminated micrites that comprise the middle portion of the formation (Fig. 2.1). Two orders of cyclicity are expressed by these strata that may correspond with the 21 Ka precessional and the 100 Ka eccentricity wavelengths of the Milankovitch spectrum. Note that four, well-defined 100 Ka cycles appear to modulate and form a single, 400 Ka eccentricity cycle, and this hierarchy of periodicities is similar to that expressed by transgressive-regressive lacustrine cycles ("van Houten cycles") of the Lockatong and Passaic formations of the Newark basin as defined by Olsen (1984, 1986) and Olsen and Kent (1996). However, such an interpretation is equivocal at best, because the maximum thickness of the cyclic interval is only ~50 m, and hence, not amenable to Fourier and the other component analyses needed to establish a cyclostratigraphic framework.

After stop turn around and retrace route to NM-209. 0.1

13.5 Bear right. **0.3**

13.8 Bulldog Mesa and Tucumcari Mountain at 12:00. **2.0**

15.8 Cross cattleguard, gate, **turn left. 0.5**

16.3 **Turn left** onto NM-209 southbound. **1.1**

17.4 Cross tributary to Plaza Larga Creek. **0.6**

18.0 Type section of Upper Triassic Redonda Formation discussed at Stop 1 was measured on point at 9:00. **0.9**

18.9 Historical marker for the notorious outlaw Black Jack Ketchum on left, Quay County road 50.4. This year is the centenary of Black Jack's execution in Clayton. The hanging was botched, and Black Jack's head was ripped from his body. The whole event was captured on film, and the gory event can be revisited at the Herzstein Museum in Clayton. **0.6**

19.5 Milepost 71. **0.3**

19.8 Cross creek. **1.7**

21.5 **Turn right** on Quay County road 48, house on right. Supplemental roadlog 3 of the 1985 NMGS Guidebook (Kues and Kietzke, 1985) ends here. **0.1**

21.6 House on right. **0.7**

22.3 Road makes sharp turn to right. **1.0**

23.3 Road makes sharp turn to left. **0.3**

23.6 Ranch houses on right. **0.7**

24.3 Abandoned ranch house on right. **0.5**

24.8 Road turns hard left. Cross cattleguard. **0.4**

25.2 Cross creek to ranch house (on left), pass house. Private land from the ranch house onward belongs to Aaron S. Parker and is managed by Rick Thompson. **0.1**

25.3 **Stay on road to right. 0.2**

25.5 Road veers left, crosses cattleguard. **0.2**

25.7 Cross cattleguard. **0.2**

25.9 Holding pens on right, **bear left. 0.1**

26.0 Stock pond. **Turn left toward gate. 0.1**

26.1 Pass through gate. **0.2**

26.3 Road enters from right. **Go left. 0.4**

26.7 Road forks, **stay left**. Circle S Mesa dead ahead, Pyramid Mountain at 1:00. **0.5**

27.2 Road to right, **continue straight. 0.3**

27.5 Cattle tank to left. **0.4**

27.9 Gate. **0.3**

28.2 Road forks, note rare, solar-powered well ahead (Fig. 2.3), **go left** (south). **0.3**

28.5 Road forks, **continue right. 0.6**

29.1 Corrals, pass through gate, road turns sharply to north. **0.7**

29.8 Cattle feeder on right, begin descent to Adobe Walls creek. This is not to be confused with the site of the Battle of Adobe Walls, which is near Stinnett in Hutchinson County, Texas. **0.2**

30.0 Road bends to right. Windmill at 8:00. **0.2**

30.2 Cross Adobe Walls creek. **0.2**

FIGURE 2.3. Solar-powered well at mile 28.2.

30.4 Road enters from left, **bear right. 0.5**

30.9 Road forks, **stay left**. Note Laramide fault between Pyramid Mountain and Circle S Mesa. **0.1**

31.0 Cattle feeder and stock tank on left. **0.1**

31.1 Road forks, **stay left**. **0.3**

31.4 Stock pond. **0.2**

31.6 Gate. **0.3**

31.9 Tank on left. **0.4**

32.3 Good view of north face of Pyramid Mountain (Fig. 2.4) displays red beds of Upper Triassic Redonda Formation of Chinle Group, overlain by yellow sandstone cliffs of Jurassic Entrada and Morrison formations capped by dome of Lower Cretaceous Tucumcari and Mesa Rica formations. **0.1**

32.4 Road curves left. **0.6**

33.0 Stock tank. **STOP 2** at north face of Pyramid Mountain (Fig. 2.4). Pyramid Mountain occupies an important place in the history of New Mexico geology. Here, on 22 September 1853, Jules Marcou, geologist of the Whipple Expedition, produced the first stratigraphic section of a sedimentary sequence in New Mexico (Fig. 2.5) and collected bivalve fossils that would later be described as *Gryphaea* (now *Texigryphaea) tucumcarii*, one of the first new species of fossil described from New Mexico (Fig. 2.6).

Marcou recognized that the basal red beds exposed here are Upper Triassic, and assigned all the overlying strata to the Jurassic, based on his belief that *G. tucumcarii* was closely related to European Jurassic gryphaeids (Kues, 1985). We now know that the thick, yellowish, cliff-forming sandstones along the face of Pyramid Mountain are

FIGURE 2.4. Two photos of Pyramid Mountain. A, From the north. B, From the west. Stratigraphic units are: 1 = Triassic Redonda Formation, 2 = Jurassic Entrada Sandstone and Morrison Formation, 3 = Cretaceous Tucumcari Formation and Mesa Rica Sandstone.

indeed Jurassic (Entrada and Morrison Formations), but that the fossiliferous shales (Tucumcari Formation) and the thick sandstone cap of the peak (Mesa Rica Sandstone) are of Early Cretaceous age.

Marcou's identification of Jurassic strata in New Mexico was his most controversial conclusion (DeFord, 1972; Kues, 1985) because Marcou assigned all of the strata defending the Llano Estacado and its erosional outliers a Jurassic age. But, the fossils Marcou collected are not true *Gryphaea* and instead belong to a closely related Early Cretaceous taxon, now called *Texigryphaea*. Thus, the shale strata at Pyramid Mountain are actually of Cretaceous age, and Marcou's error engendered a lengthy debate that was never resolved in his lifetime (DeFord, 1972; Lurie, 1974; Kues, 1985). Marcou's assignment of the underlying rocks to the Triassic lacked a paleontological basis; instead, stratigraphic position and similarity to the nonmarine Keuper (Upper Triassic) strata of Europe pro-

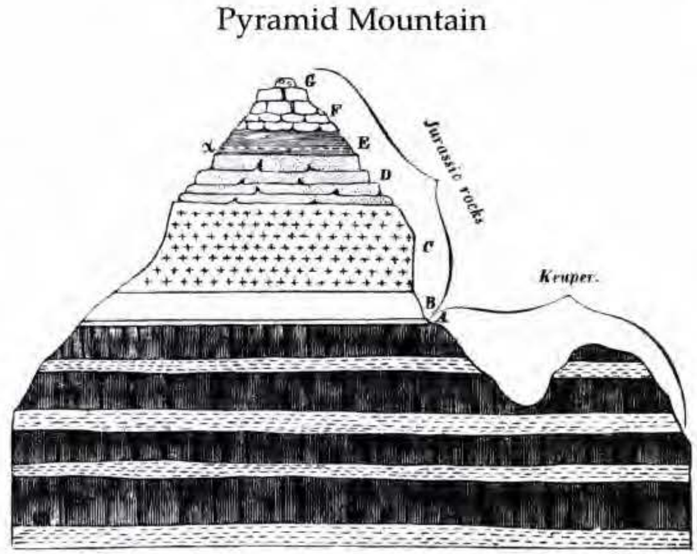


FIGURE 2.5. Marcou's (1858) drawing of Pyramid Mountain.

vided the principal basis for Marcou's determination. It is possible to directly relate the strata in Marcou's drawing of Pyramid Mountain (Fig. 2.5) to a measured section (Fig. 2.7).

After stop, begin retracing route to NM-209. 0.6

33.6 **Turn right**. (Do not go on fork straight ahead). **0.7**
34.3 Gate. **1.3**
35.6 **Stay left** on main road. **0.2**
35.8 Cross Adobe Walls creek. **0.2**
36.0 Road forks, **go left. 0.2**
36.2 Road forks, **go right. 0.7**
36.9 Gate. **0.6**
37.5 **Go left, then go right. 0.5**
38.0 Gate. **0.6**
38.6 Road to left, **continue to right. 0.6**
39.2 Road to left, **continue right. 0.3**
39.5 Road to left, **continue right. 0.2**
39.7 Road to left, **go right. 0.2**
39.9 Gate, then road curves to right. **0.3**
40.2 Cattleguard. **0.2**
40.4 Cattleguard. **0.4**
40.8 Ranch house.**0.4**
41.2 Cattleguard. **Turn right. 1.5**
42.7 Road makes sharp turn to right. **1.0**
43.7 Road makes sharp turn to left. **0.8**
44.5 Stop sign. **Turn right** and go south on NM-209. **1.0**
45.5 Quay Cemetery to right. **0.3**
45.8 Cross creek. **0.1**
45.9 Enter greater Quay. Edge of the Llano Estacado visible ahead. **0.6**
46.5 "Downtown" Quay. Virtually a ghost town now,

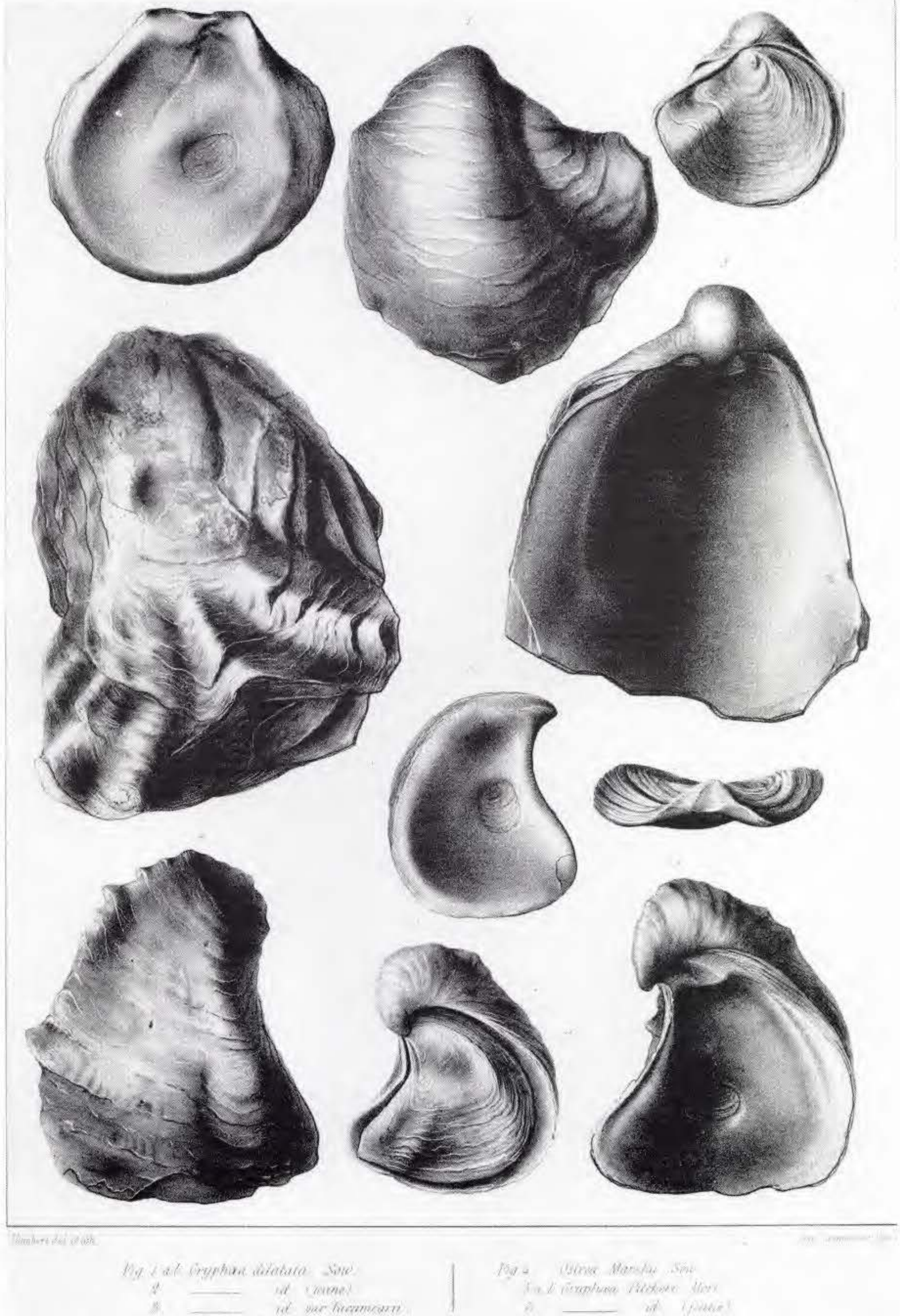


FIGURE 2.6. Copy of Marcou's (1858) plate 4, showing specimens designated as *Gryphaea tucumcarii* (fig. 3) and *Ostrea marshi* (now *Lopha subovata*: fig. 4), collected from the Tucumcari Formation at Pyramid Mountain.

FIGURE 2.7. Measured stratigraphic section at Pyramid Mountain.

Quay was settled in 1902 and named (as is the county) for Pennsylvania Senator Matthew Quay, a supporter of New Mexico statehood. **0.2**

46.7 Leave Quay. **1.0**

47.7 Red shale pit to left, QR-45 to right. **3.2**

FIGURE 2.8. Ogallala Formation overlying Triassic Redonda Formation on edge of Llano Estacado at mile 50.9.

50.9 Neogene Ogallala Formation overlies Upper Triassic Redonda Formation on left. (Fig. 2.8). The Jurassic and Cretaceous strata that topped Tucumcari Mountain, Mesa Redonda and Pyramid Mountain are no longer present here, having been removed by Cenozoic erosion prior to Ogallala deposition. However, 14 mi to the east, the entire sequence is preserved in the Bonita fault zone from near Apache Canyon to the San Jon Hill area (Stop 4 of Day 1). **0.4**

51.3 More of the same. **1.5**

52.8 Begin ascent of escarpment of Llano Estacado. **0.7**

53.5 Picnic table to left. **0.2**

53.7 Roadcut of the Upper Triassic Redonda Formation on the right. **0.1**

53.8 Neogene Ogallala Formation overlies Upper Triassic Redonda Formation on right. **Prepare to stop. 0.2.**

54.0 **Pull over on right side of the road. STOP 3.** The Neogene Ogallala Formation section here at Ragland (Figs. 2.9-2.10) has been described by Evans et al. (1949), Dolliver (1984) and Gustavson (1990, 1996). Here, the Ogallala is about 25 m thick and rests on the Upper Triassic Redonda Formation. Its lower 1.5 m are a conglomerate of well-rounded clasts of volcanic rocks, quartzite and other fine-grained metamorphics. Clasts are imbricated, and the horizontally bedded conglomerate consists of at least three, fining-upward sequences.

The basal conglomerate is overlain by pebbly sandstone and siliceous conglomerate with low angle crossbeds. A 2.4-m-thick covered interval follows below about 1.4 m of pebbly sand and gravel. These beds contain calcrete nodules and mounds, and the amount of calcrete increases upward. Above them are 6 m of pinkish-gray, fine to very fine-

FIGURE 2.9. Ogallala Formation outcrop at Stop 3.

grained sand overlain by a 2.2-m-thick massive, pedogenic calcrete, the "Caprock caliche." This complexly brecciated and recemented carbonate is a stage VI pedogenic calcrete.

Obviously, the lower part of the Ogallala section here represents fluvial deposition of coarse sands and gravels in a major channel system. In contrast, fine sands higher in the section appear to be of eolian origin—note their fine grain size, frosting of some grains and high percentage of silt- and clay-sized particles. The lack of sedimentary structures in these eolian sands is consistent with their deposition in a sand sheet, not in dunes. The pervasive development of calcic solis and calcretes also dominates the upper part of the section.

Reworked basalt clasts in the basal conglomerate can only have come from the Ocate or Raton basalt field to the north. These fields are about 8 Ma (late Miocene) at oldest (Størmer, 1972; Mehnert and O'Neil, 1991), so this is a maximum age of the Ogallala Formation at Ragland.

After stop, **continue south on NM-209 into Ragland. 0.2**

54.2 Enter Ragland as road bends to east, and climb atop Llano Estacado. Continue on NM-209. **6.1**

60.3 Junction with NM-268 to Melrose. Continue straight. **1.9**

62.2 Cross swale. **0.1**

62.3 Junction with NM-210 to Forrest. Continue straight. **2.9**

65.2 Playa to right. **3.4**

68.6 Cross large playa lake deposits. The High Plains are

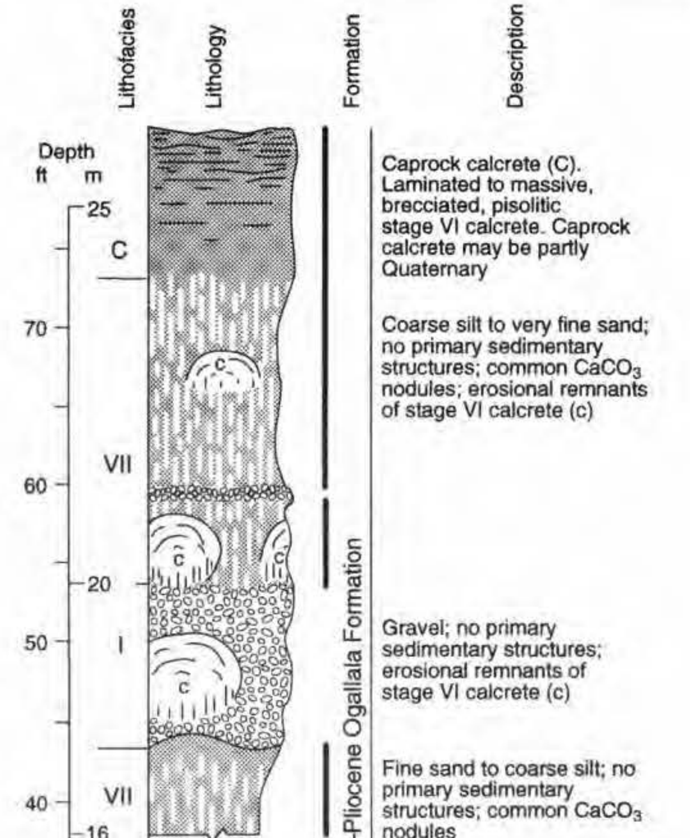


FIGURE 2.10. Measured section of Ogallala Formation at Stop 3 (from Gustavson, 1996).

dotted with circular playa lakes. These depressions are caused either by subsidence or deflation **1.3**

69.9 Playa to left. **1.5**

71.4 Junction with NM-278 to Norton. Continue straight. **2.5**

73.9 Mile marker 40. Very large playa to left. **0.6**

74.5 Enter Curry County, named for George Curry, Territorial Governor in 1909, when the county was formed. **0.9**

75.4 Playa to right. **3.0**

78.4 Enter Grady. **0.2**

78.6 Junction with NM-469 to San Jon. Continue straight. **0.5**

79.1 Leave Grady. **5.0**

84.1 Enter Broadview. **0.4**

84.5 Junction with NM-241 to Bellview. **Continue on NM-209** as it bends to the right (south). **0.7**

85.2 Leave Broadview. **5.4**

90.6 Junction with NM-19. Continue straight. **4.2**

94.8 Cross Frio Draw. **3.1**

97.9 Junction with NM-289. **Stay left on NM-209 to Clovis. 2.9**

100.8 Junction with NM-288 to NMSU Agricultural Science Center. Continue straight. **1.0**

101.8 Curry County Road 22 to left. **1.0**

102.8 Curry County Road 21 to right and left. **1.0**

103.8 Junction with County Road 20. Continue straight. This area, from north of Clovis south to Portales, is by far New Mexico's richest agricultural area. Curry and Roosevelt Counties account for about 25% of the irrigated and 60% of the dryland farming acres in the state, providing mainly wheat, corn and sorghum. Curry County also ranks among the top three counties in New Mexico in total cattle population. Clovis has the largest grain storage capacity in the state and manufactures more livestock feed than any city west of Kansas City. **1.0**

104.8 Curry County Road 19. **0.5**

105.3 Cross Running Water Draw. **0.5**

105.8 Ned Houk Park to left. **1.1**

106.9 Junction with County Road 17. Continue straight. **1.0**

107.9 Junction with County Road 16. Continue straight into greater Clovis. **2.0**

109.9 Junction with NM-77 to left; continue straight. **1.1**

111.0 Clovis city limits. Clovis (population 32,000 in 1998), named after a local ranching family, began in 1906 as Riley Switch. The name was changed to Clovis in 1907 when the Atchison, Topeka and Santa Fe Railroad was completed through the town. Agriculture quickly became the dominant economic activity, especially with the beginning of deep-well pumping for irrigation in the 1940s. Establishment of Cannon Air Force Base nearby in 1942 also bolstered the city's growth. **1.0**

112.0 Junction with NM-245 (Llano Estacado Boulevard). **Continue straight** through several traffic lights. **1.0**

113.0 Continue through traffic light (21st Street) south on NM-209. **1.5**

114.5 Junction US-60/84 and US-70. **Continue straight and cross bridge over railroad.** At this point, NM-209 becomes US 70 west. **2.5**

117.0 Leaving Clovis. **2.2**

119.2 Note large assemblage of fossil tractors in field to right, index fossils of the late Holocene. **1.9**

121.1 Roosevelt County line. **0.9**

122.0 Large dune on left. Note dunal topography here for the next few mi. The dunes in this area are part of the west-east-trending Muleshoe dunes that extend in a strip about 110 mi long and less than 10 mi wide (Reeves, 1972, 1973). **1.9**

123.9 Sign says Blackwater Draw Museum 2 mi. **2.0**

125.9 **Turn left** into parking lot for Blackwater Draw Museum. **0.1**

126.0 **STOP 4.** Blackwater Draw Museum, showcasing the archeology, paleontology, and geology of the famous Blackwater Locality No. 1. Opened to the public in 1969, the Museum is part of Eastern New Mexico University in Portales. Its exhibits detail the Blackwater Draw Paleoindian site, first discovered in 1932, which is the type locality of the Clovis culture, where human tools (Clovis points: Fig. 2.11) were found associated with extinct late Pleistocene mammals, such as mammoth, camels, horse and bison. The site was incorporated into the National Register of Historic Places in 1982. Humans occupied it as early as about 11,500 years ago. Indeed, there are multiple levels of human occupation (i.e., the site is "stratified") from the late Pleistocene into the Late Prehistoric Period (Fig. 2.12), one of the nearly unique and extremely important features of Blackwater Locality No. 1.

After stop return to US-70. 0.1

126.1 **Turn left** onto US-70. **0.7**

126.8 Junction with NM-202. Continue straight. **1.0**

127.8 Entering another dune field. **2.5**

130.3 Sign says turn right in 1 mile to go to Blackwater Draw site. **1.0**

131.3 Note Portales city limit sign, then **turn right at junction with NM-467.** Portales is older than the more populous Clovis. Springs once issued from seven caves that early Spanish settlers called Las Portales because the overhanging cliffs resembled porches ("portales") of Spanish adobe houses (Julyan, 1996). Las Portales became an important water stop on the Fort Summer Trail. Billy the Kid

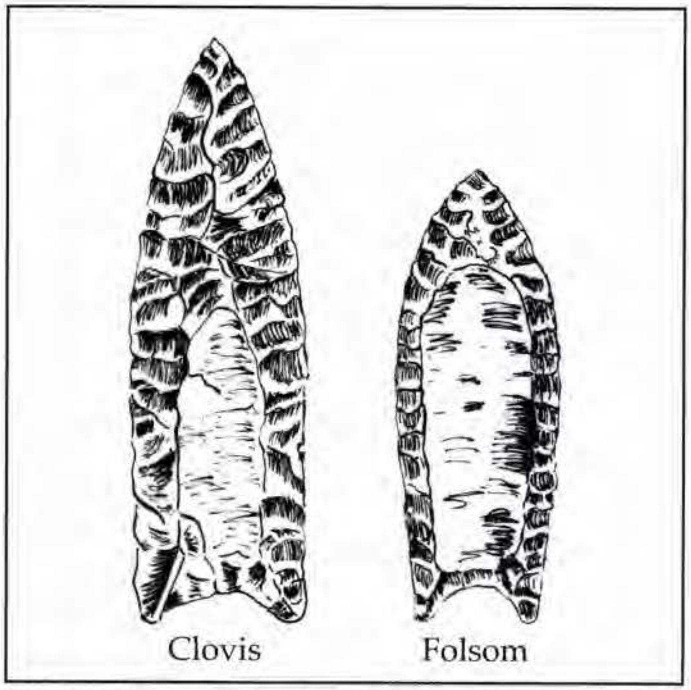


Figure 2.11. Clovis and Folsom points (after Agogino and Eaton, 1972).

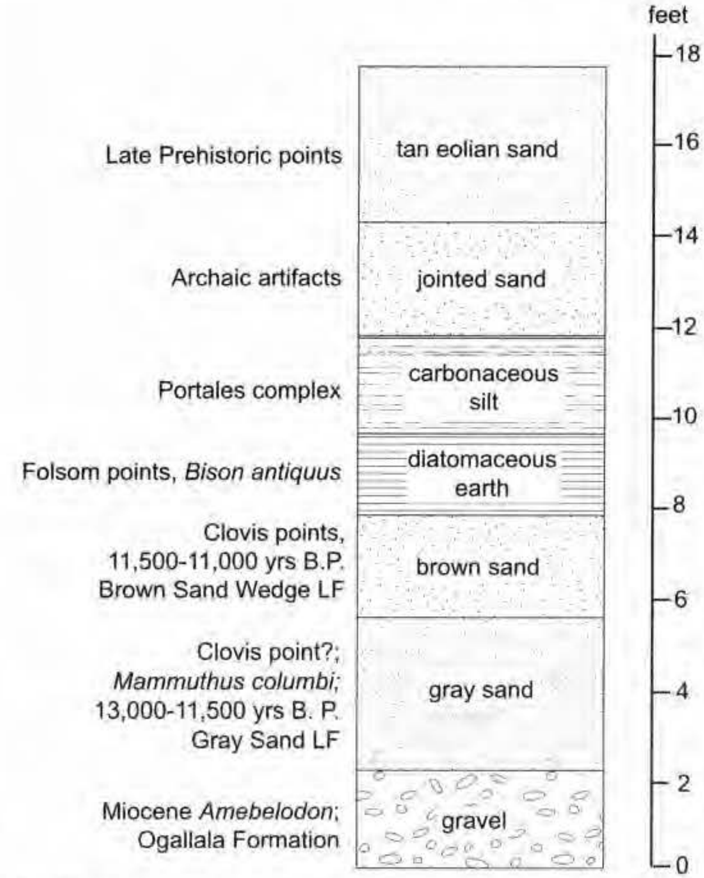


FIGURE 2.12. The classic stratigraphy at Blackwater locality No. 1.

camped at the springs, and it is said that he dreamed of building a ranch at Las Portales. Josh Morrison built a store in the late 1800s, and soon afterward the Pecos Valley and Northeastern Railroad built a construction camp nearby. A post office was established in 1899, and the town's name was shortened to Portales. Today the springs are dry because of pumping for irrigation. Portales is home to Eastern New Mexico University, established in 1934. Agriculture, especially dairy production, is a major industry for both the Portales and Clovis areas. **2.0**

133.3 Enter another vegetated dune field. **1.9**

135.2 Junction with turn to Oasis State park and historical marker (see accompanying minipaper). Continue straight. **1.2**

OASIS STATE PARK

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Oasis State Park lies 18 mi southwest of Clovis and 7 mi north of Portales via US-60 and NM-467. It was established in 1961 to preserve a true oasis in the sandy desert of the Llano Estacado or "staked plains" of the Great Plains physiographic province. The surrounding area is flat, treeless, featureless and relatively dry. The summers are hot, the winters are cold, and the wind seems to blow constantly. In contrast, the park offers shade trees and a pond, as well as the conveniences such as water, showers, electric hookups and dump stations expected of picnic areas and modern campgrounds (Fig. 2.13). Many of the facilities are accessible to people with disabilities. In addition to picnicking and camping, fishing, hiking and bird watching are popular activities. The pond is stocked with catfish and trout. Trails weave up, down and around the sand dunes. A ballfield lies near the center of the park.

The area is known to have been occupied by man about 11,500 yrs ago as evidenced by stone tools and projectile points found at nearby Blackwater Locality No. 1 (Agogino and Egan, 1972, Holliday, 1995, Haynes, 1995). At the Blackwater Draw archaeological site, projectile points were found with fossil remains of late Pleistocene fauna, including mammoth, camel, horse, bison, sabertooth tiger and dire wolf. A large pond at the site attracted the game animals and hunters, including man, from approximately 11,500 to 6000 yrs ago (Hester, 1972). Evidence indicates that the winters were warmer than today, and the summers were cooler; permanent streams and rivers were common. The oldest artifacts are of the Clovis or Llano culture; they are spear points, cutting tools and a butchered mammoth. The Clovis culture was dominant in this area from about 11,000 to 9000 B.C. It was followed by the Folsom culture from about 10,000 to 8000 B.C. Other, lesser-known cultures followed, including Portales and Archaic (Agogino and Egan, 1972; Hester, 1972; Haynes, 1995). About 7000 yrs ago, the pond dried up following widespread change in the climate, but humans continued to occupy the area as evidenced by camp fires, hand-dug wells and butchering sites.

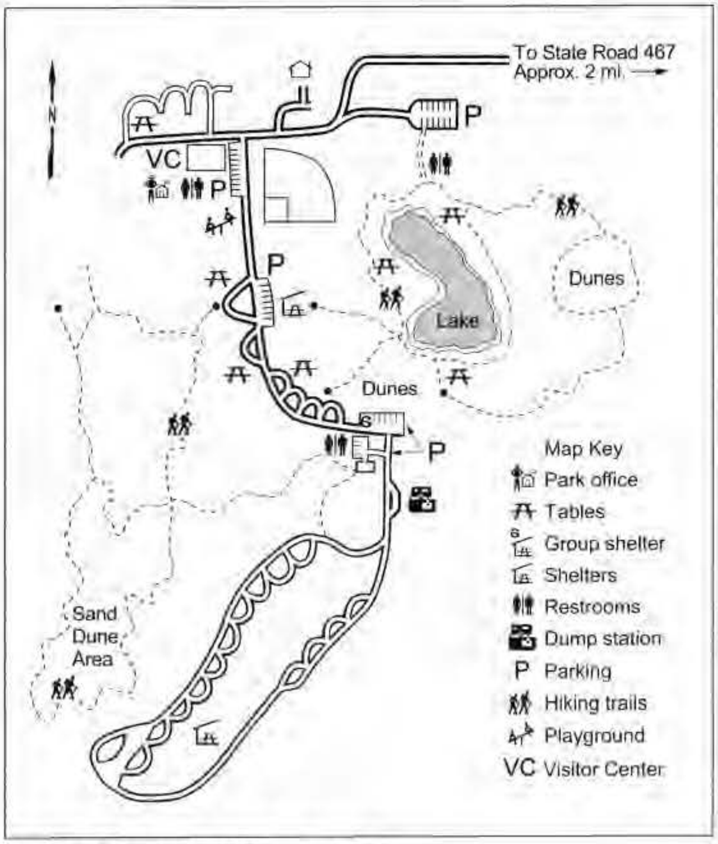

FIGURE 2.13. Map of Oasis State Park.

Finally, the site was abandoned about 4950 yrs ago as the water completely dried up (Hester, 1972).

Later, Comanche, Cheyenne and Kiowa roamed these plains; subsequently, settlers migrated into the area and lived in sod huts and depended on buffalo chips for heat. Numerous cattle drives went through the area in the 1800s. Early settlers came and dug shallow wells to tap the high water table; the stagnant water quickly turned dark, hence the name Blackwater Draw (Julyan, 1996). In 1902, a homesteader, Will Taylor, settled at the present location of Oasis State Park and planted cottonwood, chinaberry, locust, elm and cedar trees. Some of these trees still stand within the state park. Before the area became a state park, it was known as Taylor's Grove, a popular picnicking site (Young, 1984). The natural artesian springs that attracted Taylor to the area have long since dried up as a result of heavy irrigation. Now water is pumped from a well to feed a four-acre pond. The pond also serves as a stopover for migratory waterfowl.

In 1932, Walter Burns, a New Mexico State Highway Department engineer, discovered bones in a gravel pit being quarried for construction of US-70. Burns contacted archaeologists at the University of New Mexico, and excavations began at the quarry now known as Blackwater Locality No. 1 north of the state park. Studies were also conducted by the University of Pennsylvania in 1932-1937 (Katz, 1997). Research over the next 30-40 years slowly pieced together the prehistory of the area (Haynes, 1995; Holliday, 1995; Katz, 1997).

Oasis State Park is in the Portales Valley, an inset in the Llano Estacado. The Llano is formed on the Ogallala Formation. The Ogallala Formation consists of eolian (wind-blown) sand and silt and fluvial (stream or river) and lacustrine (lake) sand, silt, clay, and gravel derived from the Rocky Mountains between mid-Miocene to early Pliocene time, about 3–12 Ma (Reeves, 1972; Hawley, 1984, 1993; Gustavson et al., 1991). These surficial deposits were reworked and deposited by water and wind. In many places a caprock of hard, impermeable calcium carbonate, locally called caliche, formed near the surface in arid conditions during the early Pliocene or later. This caprock forms the rim of the Llano Estacado and is about 10–40 ft thick in the Clovis-Portales area (Galloway, 1956, 1972). It consists of fractured and permeable deposits of gravel, sand, silt and clay that are cemented by calcium carbonate (McGrath and Hawley, 1985). It is used locally for crushed and decorative stone. The caprock is a calcrete and is formed primarily by the process of downward percolation of surface waters depositing calcium carbonate in the upper soil horizons within the Ogallala Formation and perhaps, even in the overlying Blackwater Draw Formation and recent eolian deposits (Bachman, 1976; McGrath and Hawley, 1985). Important aquifers (reservoirs of ground water) occur in the Ogallala Formation, and they supply much of the water used for livestock, irrigated farms and recreation areas such as the state park. Much of this water originally was derived from the Sangre de Cristo Mountains before the Pecos River captured most of the water now migrating from those mountains. The only recharge or new water to the Ogallala aquifer in this area of New Mexico-Texas is from rain along the Llano Estacado. Pumping for irrigation and municipal use is depleting the aquifer much faster than it is being recharged!

The Pleistocene Blackwater Draw Formation overlies the Ogallala Formation in parts of Curry and Roosevelt Counties and consists of thin, silty to clayey soils and eolian sands. The Blackwater Draw Formation was formed by episodic cycles of eolian deposition during dry periods, followed by subhumid to semiarid conditions forming more cemented soils. Numerous cycles occurred for at least 1.6 million years to form the Blackwater Draw Formation. This unit is as thick as 81 ft and extends from the Pecos River valley eastward to Amarillo and Lubbock, Texas (Holliday, 1989). The grain size of the soils decreases from the southwest (predominantly sand) to the northeast (predominantly silt), indicating that the source was the Pecos River valley (Holliday, 1989). Three ash units occur in the formation and have been dated as 1.61 Ma (Guaje or Otowi Ash), 1.59 Ma (Cerro Toledo Ash) and 1.22 Ma (Tshirege Ash). These ash beds were formed by ash erupted and blown by the wind from the Jemez volcanic field (Izett et al., 1972; Gardner and Goff, 1996; Spell et al., 1996). The Brazos River flowed through the Portales area earlier and deposited the gravels that localized the pond used by prehistoric man at Blackwater Locality No. 1 (Taylor and Pitt, 1972; Hester, 1972; Holliday, 1995). During the Pleistocene, the Pecos River captured the Brazos River, and the springs were formed. The springs fed the pond at the Blackwater Draw archaeological site.

Recent sand dunes locally overlie the Blackwater Draw Formation. At the state park, these sand dunes are white because the sand is composed of medium-to fine-grained, white to clear

FIGURE 2.14. Photograph of north bank stratigraphy at Blackwater locality No. 1 taken in December 1962 or January 1963. Strata are: 1 = spoil, 2 = "jointed sand," 3 = "carbonaceous silt," 4 = laminated zone, 5 = white sand lens, 6 = Folsom and Midland zone, 7 = Clovis gray sand, 8 = gravel, 9 = red clay lens. Courtesy of Joanne Dickenson and the site archives of Blackwater Draw locality no. 1.

quartz, gypsum, calcite and feldspar crystals. Most of the dunes are crescent-shaped in plan view because they are formed by constant wind on a flat desert floor; these are called barchan dunes. Parabolic dunes, which are also crescent shaped, are locally formed by wind from the opposite direction.

Acknowledgments—Special thanks to the state park personnel and Joanne Dickenson, curator of the Blackwater Draw Locality No. 1, for discussions and information on the history of the park and Blackwater Draw Locality No. 1. Frank Kottlowski, Bruce Harrison and Dave Love reviewed an earlier version of this manuscript, and their comments are appreciated. The New Mexico Bureau of Geology and Mineral Resources Cartography Department drafted the figure.

136.4 **Turn left** to Blackwater Draw site. Blackwater Draw Locality No. 1 historical marker to right; drive through gate to the parking area at the building that covers the site. **0.4**

136.8 **STOP 5.** Blackwater Draw locality no. 1 is the type locality of the Clovis culture, long considered to be the oldest New World culture (older sites are now known). The site was originally a gravel pit, and in 1932 mammoth bones were discovered in association with large, fluted projectile points (Katz, 1997), later termed "Clovis points" (Fig. 2.11). Excavations for artifacts and fossils began from 1932-1937, then restarted in 1948-1956 and have continued on and off since. These excavations and related geological studies (e.g., Haynes, 1995; Holliday, 1997) establish that the Clovis site was a natural depression occupied initially by a late Pleistocene lake.

FIGURE 2.15. Pedestalled mammoth bed and north wall of excavation of Blackwater Locality No. 1. Photo taken 15 December 1962, courtesy of Joanne Dickensen and the site archives of Blackwater Draw locality no. 1.

This basin is inset in the Pleistocene Blackwater Draw Formation and underlying gravels of the Ogallala Formation, which are latest Miocene (6-7 Ma) in age (see accompanying minipaper).

The paleobasin here contains a stratified fill (Figs. 2.12, 2.14). The oldest fill is spring-deposited sands about 11,000-13,000 years old that grade toward the basin margin into sand and rubble eroded from the valley walls. These sands have yielded the Clovis points, associated mammoths (Fig. 2.15) and other mammals. Indeed, remains of at least eight mammoths and two bone beds of *Bison antiquus* are present in these sands. Although long believed to be a mammoth kill site, the mammoths here were actually scavenged (Saunders and Daeschler, 1994). However, the bison do appear to have been killed and butchered by the Clovis hunters.

Above the Clovis stratigraphic level is diatomaceous earth interbedded with mud and sand that dates back to 10,000-10,800 years ago. It yields Folsom tools and other *Bison* bone beds. Other Folsom features occur in eolian sands on the uplands northwest of the ancient basin. Overlying strata, the "carbonaceous silt" (pond and marsh deposits), contain Late Paleoindian artifacts and *Bison* bones dating to about 10,500-8,500 years ago. The section at the site (Figs. 2.12, 2.14) thus exposes multiple levels of occupation.

After stop return to highway. 0.4

THE SHOVEL-TUSKED GOMPHOTHERE *AMEBELODON* (MAMMALIA: PROBOSCIDEA) FROM THE MIOCENE OGALLALA FORMATION AT THE BLACKWATER DRAW SITE, ROOSEVELT COUNTY, NEW MEXICO

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Blackwater Draw, in Roosevelt County, east-central New Mexico, is the type Clovis site, and one of the best known localities in North America that documents the association of Paleoindians with a diverse assemblage of extinct Pleistocene megafauna (Hester, 1972; Lundelius, 1972; Haynes, 1995). The Clovis level at Blackwater Draw, also called the "Gray Sand," is latest Pleistocene in age. However, a much older, late Miocene mammal, the shovel-tusked proboscidean *Amebelodon*, was recovered from a lower stratigraphic level at Blackwater Draw during gravel mining operations in the early 1960s.

The *Amebelodon* fossil consists of a right dentary with m2 and partially erupted m3 (Fig. 2.16). The mandible was discovered in December 1962 or January 1963 during gravel mining operations in the North Pit at Blackwater Draw by J. D. Murray, a dredge operator for the Sanders Sand and Gravel Company. The *Amebelodon* jaw was derived from gravels of the Miocene Ogallala Formation, which unconformably underlies the late Pleistocene Clovis or Gray Sand level. Unfortunately, the two photographs reprinted here (Fig. 2.16) and another photograph in Katz (1997, p. 2) are the only tangible evidence now available of this fossil. The jaw was retained in J. D. Murray's private collection for many years, but after his death the fossil disappeared, and attempts to locate it have been unsuccessful (Joanne Dickenson, oral commun., 2000).

Even though the Miocene proboscidean mandible from Blackwater Draw cannot be located, the photos of the specimen are sufficient to reveal several aspects of its morphology that are diagnostic of the genus *Amebelodon*. In Figure 2.16 a lateral view of the right dentary shows that the m2 is tetralophodont (i.e., it has four lophids). The m3 is not fully erupted but has four unworn lophids visible. The tetralophodont condition of the m2 is characteristic of advanced species of *Amebelodon* (subgenus *Konobelodon*), whereas more primitive species of *Amebelodon* (subgenus *Amebelodon*) have only three lophids on m2 (Lambert, 1990). One other proboscidean known from New Mexico, the

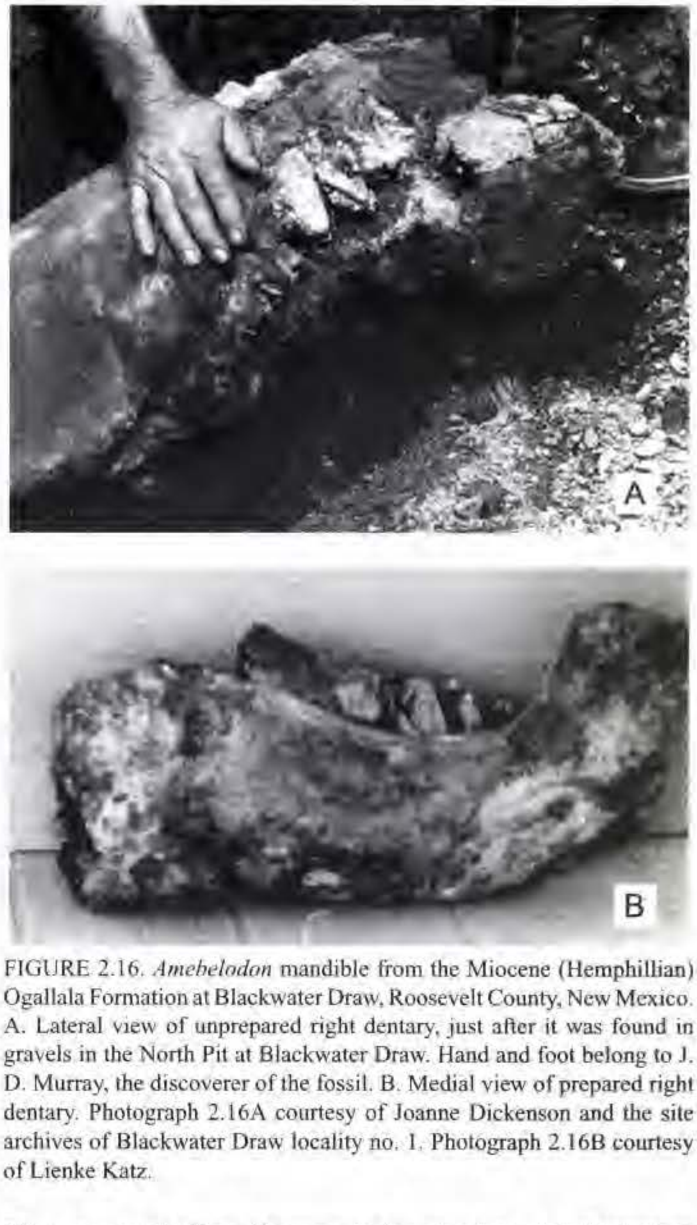

FIGURE 2.16. *Amebelodon* mandible from the Miocene (Hemphillian) Ogallala Formation at Blackwater Draw, Roosevelt County, New Mexico. A. Lateral view of unprepared right dentary, just after it was found in gravels in the North Pit at Blackwater Draw. Hand and foot belong to J. D. Murray, the discoverer of the fossil. B. Medial view of prepared right dentary. Photograph 2.16A courtesy of Joanne Dickenson and the site archives of Blackwater Draw locality no. 1. Photograph 2.16B courtesy of Lienke Katz.

Pliocene gomphothere *Stegomastodon*, also has a tetralophodont m2. However, *Stegomastodon* has a very short mandibular symphysis and lacks lower tusks, whereas the Blackwater Draw fossil has a robust mandibular symphysis and would have possessed a pair of large, shovel-shaped lower tusks.

Although the gomphothere jaw from Blackwater Draw is broken anterior to m2, enough of the horizontal ramus is preserved (Fig. 2.16) to reveal two other important morphological characters. The horizontal ramus increases in depth gradually from below m3 anteriorly, reaching its greatest depth just anterior to the anterior edge of the toothrow. At the anterior edge of the toothrow, the dorsal margin of the horizontal ramus curves noticeably dorsally, and the ventral edge curves somewhat ventrally, which in combination greatly increases the depth of the dentary. The strong dorsal curvature and deepening of the horizontal ramus just anterior to the toothrow are very characteristic of *Amebelodon*, probably reflecting the strengthening of the mandibular symphysis necessary to support the massive shovel tusks of this genus. Figure 2.16 also reveals the presence of a narrow, deep groove between the right and left dentaries just anterior to the toothrow, another feature typical of *Amebelodon*.

The morphological characters of the teeth and dentary evident in Figure 2.16 confirm the presence of the shovel-tusked gomphothere *Amebelodon* from the Ogallala Formation at Blackwater Draw. Furthermore, the presence of a tetralophodont m2 indicates that this dentary is referable to the subgenus *Konobelodon*. *Amebelodon* (*Konobelodon*) has a restricted stratigraphic range in North American late Miocene faunas (Lambert, 1990), where it is known from the late early Hemphillian (about 7 Ma) of Florida and the early late Hemphillian (about 6 Ma) of Kansas. The youngest occurrence of *Amebelodon* is in faunas equivalent in age to the Coffee Ranch local fauna in the Texas Panhandle, the type fauna of the Hemphillian land-mammal "age" (Schultz, 1977). *Amebelodon* is unknown after the early late Hemphillian (Lambert, 1990), so its presence establishes an age of 6 Ma or older for the Ogallala Formation at Blackwater Draw.

The primary importance of the Blackwater Draw *Amebelodon* is that the restricted biostratigraphic range of this genus establishes a fairly narrow age interval (latest Miocene, between 6 and 7 Ma, possibly somewhat older) for the Ogallala Formation in eastern New Mexico. The only previously reported fossils from the Ogallala Formation in New Mexico are a mammalian footprint fauna from San Juan Mesa in Chaves County (Williamson and Lucas, 1996). The San Juan Mesa footprint fauna, which includes a large cat, a large camel, a smaller artiodactyl, and perhaps a dog, does not provide any further information on the age of the Ogallala Formation in New Mexico (Williamson and Lucas, 1996).

137.2 **Turn left** onto NM-467. **1.8**
139.0 Curry County line. **2.1**
141.1 Large stockyard to left. **1.9**
143.0 Junction with road to left to Cannon Air Force Base; continue on NM-467 through right bend in road. **3.0**
146.0 Sharp left bend in road. **2.7**
148.7 Cross railroad. **0.3**
149.0 Stop sign. Junction with US-60/84, **turn left. 2.9**
151.9 Exit for Cannon Air Force Base/Junction NM-311 to right. Continue straight. **9.9**
161.8 Don't miss St. Vrain (dating back to 1907) on right. **3.4**
165.2 Junction with NM-224. Continue straight. **4.1**
169.3 Junction with NM-267; entering Melrose (population 660 in 1990). Melrose began in 1882 as a village named Brownhorn; the Santa Fe railroad came through in 1906 and selected the town as a site for a roundhouse. **0.6**
169.9 **Turn right** at junction with NM-268. **0.1**
170.0 **Turn right** to continue north on NM-268. **0.3**
170.3 Downtown Melrose; most stores are empty and boarded up. **0.2**
170.5 **Veer left** to continue on NM-268. **0.3**
170.8 Road turns sharply left. **0.2**
171.0 Road turns sharply right. **10.0**
181.0 Junction with NM-89. Continue straight. **3.9**
184.9 Junction with NM-288. Continue straight. **4.1**
189.0 Junction with NM-312 at Quay County line. Continue straight. **7.1**
196.1 Junction with NM-210. Continue straight. **2.0**
198.1 Stop sign. **Turn left** at junction with NM-209 to retrace our route this morning. **5.9**
204.0 Enter Ragland. Continue north on NM-209 towards Tucumcari. **0.3**
204.3 Stop 3 of this morning; descend from the Llano Estacado. **7.4**
211.7 Quay. **3.0**

LAGUNA COLORADO: A FORGOTTEN HOLOCENE LAKE IN QUAY COUNTY, NEW MEXICO

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On 5 October 1841, the main body of an ill-fated Texas-Santa Fe expedition of General Hugh McLeod surrendered to the Mexicans on the shores of the only substantial lake in east-central New Mexico at that time--Laguna Colorado (Carroll, 1951). Laguna Colorado (or Laguna Colarada) was a well-documented lake in the nineteenth century. Josiah Gregg stopped there in 1839 (Gregg, 1844). Subsequently, several exploratory expeditions camped at the lake and mapped its location (Simpson, 1850; Marcy, 1852; Marcou, 1858). None of these expeditions recorded the presence of any other lake in east-central New Mexico; notably there is no mention of Tucumcari Lake. Capt. R. B. Marcy and Lieut. J. H. Simpson were members of the same expedition and published separate maps of the area (Simpson, 1850; Marcy, 1852). Simpson's (1850) map (reproduced by Kues, 1985) shows Laguna Colorado as an elongate, northeast-trending lake drained by a northeast-flowing drainage.

Carroll (1951) located Laguna Colorado approximately 4 mi southeast of the village of Newkirk in Guadalupe County, and Kues (1985) gave a similar location for the surrender of the 1841 expedition. Marcy (1852) and Simpson (1850) show Laguna Colorado as located just south of the 35th Parallel at about 104° 15' W. Marcou (1858) shows the lake at about the same longitude, but just north of the 35th Parallel. Carroll (1951) estimated that the 1841 camp was about 0.5 mi north of the common corner of townships 26 and 27 E.

How long did Laguna Colorado exist? Obviously, the lake was in existence in 1839 (Gregg, 1844) and probably long before that time. In May 1858, a survey along the range line between Range 26 East and 27 East had to triangulate across a lake a distance of 6.07 chains. A later resurvey in February and March of 1881 recorded no lake. However, at the point where the previous survey had been forced to triangulate, they recorded a northeast-flowing arroyo (Carroll, 1951). Thus, it appears that between 1858 and 1881, Laguna Colorado ceased to exist, or at least it became much smaller. Local residents still remembered the lake as late as 1935 (Carroll, 1951).

What became of the lake? Carroll (1951) hypothesized that the area was overgrazed by sheep, resulting in increased erosion. Subsequently, Bull Canyon Creek cut a deep canyon across the plain into the eastern end of the holding basin of Laguna Colorado and drained it. Laguna Colorado was obviously a significant geographic feature in east-central New Mexico at least in the nineteenth century and maybe for a significant time prior to that.

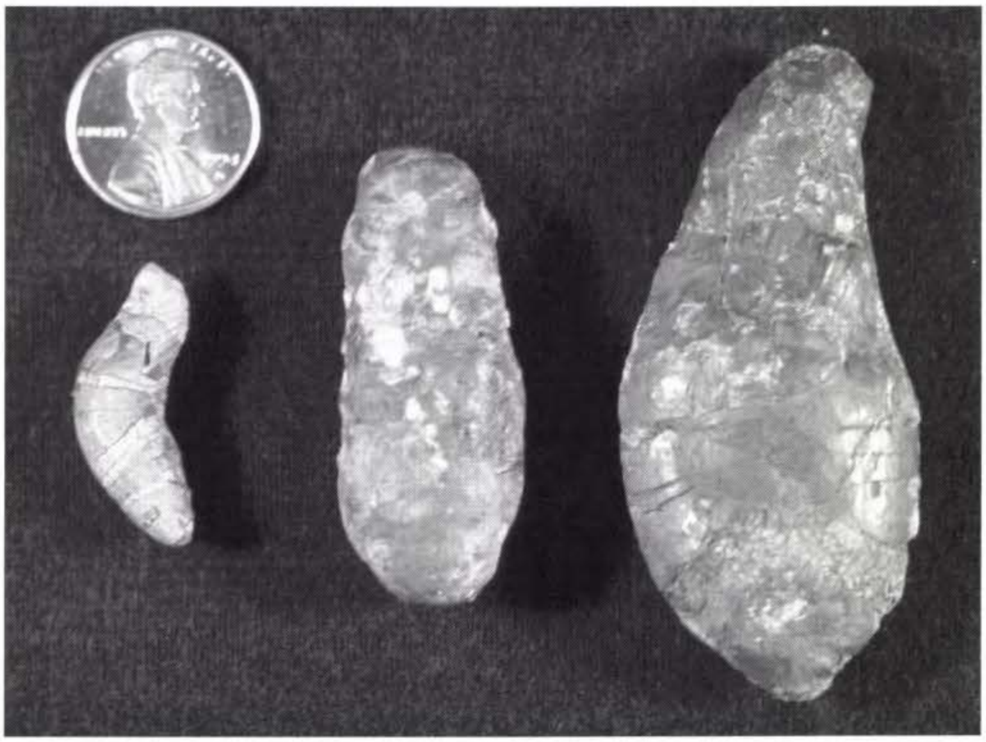
214.7 Tucumcari Mountain in distance, straight ahead. **12.9**

227.6 Tucumcari city limits. **1.7**

229.3 Traffic light at Tucumcari Boulevard. Continue straight. **0.2**

229.5 Turn right at Laughlin and stop at museum.

End of Second-day Road Log.



Coprolites such as these are fossilized feces of Late Triassic amphibians and reptiles. They are among the most common fossils found in Chinle Group strata in east-central New Mexico.