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Third-day road log, from Tucumcari to Conchas Dam, New Mexico

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THIRD-DAY ROAD LOG, FROM TUCUMCARI TO CONCHAS DAM, NEW MEXICO

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

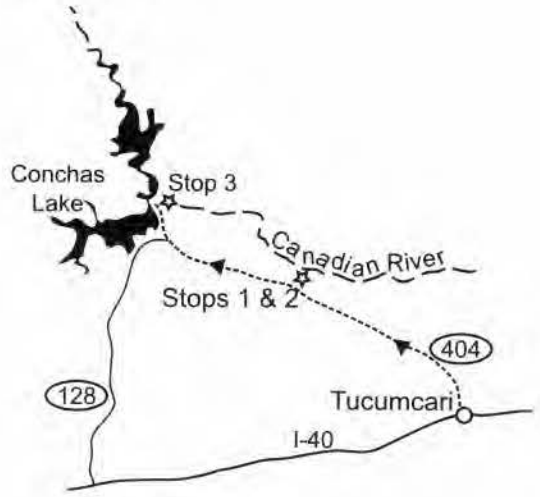
SATURDAY, SEPTEMBER 29, 2001

Assembly point: Mesalands Dinosaur Museum, 222 East Laughlin, Tucumcari
Departure time: 8:00 AM
Distance: 34.2 miles
Stops: 3

SUMMARY

This trip explores the geology of the Canadian River drainage from Tucumcari north to Conchas Dam. Here, we contrast differences between the beginning and the end of Late Triassic deposition in the vast Chinle basin, and the continuity of Middle Jurassic eolian deposition across the American Southwest.

At STOP 1 we examine an unusual lithofacies of the Upper Triassic Redonda Formation. At STOP 2, a roadcut fortuitously created a three-dimensional exposure of the Middle Jurassic Entrada Sandstone, which facilitates discussion of Middle Jurassic wind patterns and paleogeography. STOP 3 ends the fieldtrip at Conchas Dam, where the onset of Chinle Group deposition in the western United States is featured.



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 right** (north) on First Street (NM-104) and proceed north. **0.3**

0.4 **Move into center lane** and proceed through traffic light at Main Street, continue straight. **0.2**

0.6 Cross bridge over railroad tracks. **0.4**

1.0 Leave Tucumcari. **1.3**

2.3 Crest ridge in dune field, Liberty Mesa at 9:00-11:00; note that to the north the Canadian escarpment is visible in the distance. **0.6**

2.9 Red-bed Chinle mudstones apparent beneath alluvium to right in roadcut are probably part of the Bull Canyon Formation. **0.1**

3.0 Cross Pajarito Creek, namesake of the Lower Cretaceous Pajarito Formation. The late Albian index ammonite *Mortoniceras equidistans* was found just south of here in the basal Mesa Rica Sandstone (Lucas and Hunt, 2000). **1.9**

4.9 Low exposures of Upper Triassic Chinle Group red-bed mudstones (probably Bull Canyon Formation) on right of road. Note Laramide folds and faults in this area disrupt the Mesozoic (mostly Lower Cretaceous) strata (see accompanying minipaper). **0.4**

THE LARAMIDE TUCUMCARI STRUCTURAL ZONE, EAST-CENTRAL NEW MEXICO

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Northeastern New Mexico is characterized by an apparent lack of structural complexity and a sedimentary cover with very low regional dips. The only major structure to appear on large scale geologic maps (e.g., Dane and Bachman, 1965; Clemons, 1982) is the Bonita fault zone in southeastern Quay County and northern Roosevelt County (Stearns, 1972). The purpose of this paper is to demonstrate that east-central New Mexico actually has a more complex Laramide structural history.

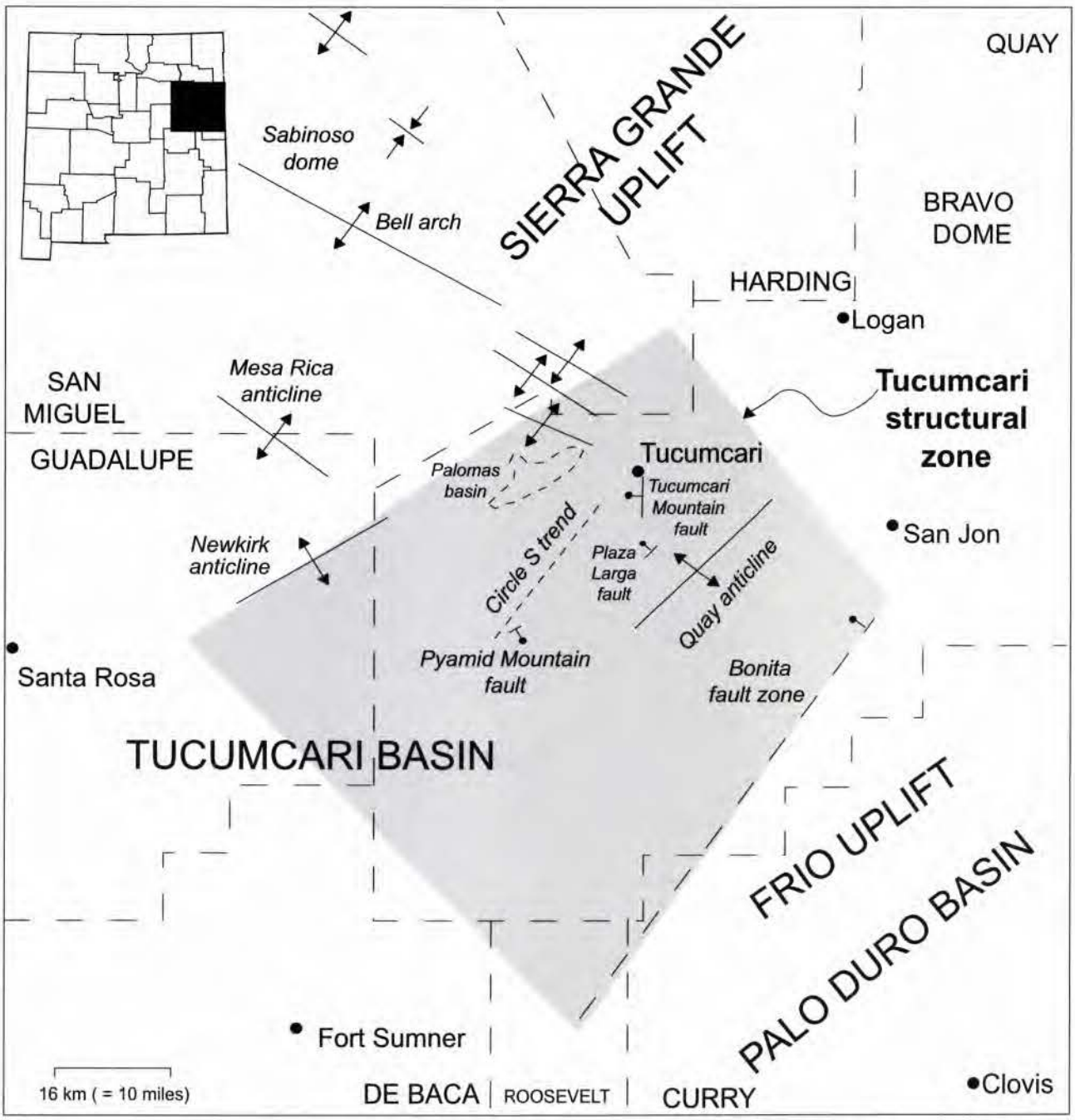


FIGURE 3.1. Simplified structural map of east-central New Mexico showing the Tucumcari structural zone and related features (data from Dobrovolny et al., 1946; Berkstresser and Mourant, 1966; Stearns, 1972; and original observations).

Stearns (1972, fig. 1) provided a structural sketch of east-central New Mexico that implied that there were very few structures in the area. However, the little detailed mapping that has been done in the area demonstrates greater structural complexity (Fig. 3.1; Dobrovolny et al., 1946; Wanek, 1962). From Tucumcari to the southwest, there is a northeast-trending series of structures that we term the Tucumcari structural zone. This zone is bounded on the northwest by the Newkirk anticline and on the southeast by the Bonita fault zone (Fig. 3.1). Most structural features within this zone trend northeast, whereas northwest-trending structures terminate the Tucumcari structural zone to the north/northwest. Neogene strata cover the northeastern and southwestern ends of the Tucumcari structural zone, so its full extent is unclear.

The majority of structures in the Tucumcari structural zone are gentle folds that trend northeast and include, from northwest to southeast: (1) the Newkirk anticline of Stearns (1972); (2) the Palomas basin, which we name for the structural basin mapped by Dobrovolny et al. (1946) that extends to the northeast from Palomas; and (3) a northeast-plunging anticline, originally mapped by Dobrovolny et al. (1946) as extending from Mesa Redonda to the area where Revuelto Creek crosses I-40, that we name the Quay anticline. There is also a northeast trend of small structural basins

extending from Circle S Mesa in the southwest to the Five Mile Park area west of Tucumcari (Dobrovolny et al., 1946) that we term the Circle S trend. This trend probably represents a series of dissolution features aligned along a fault zone. These structures, particularly the Quay anticline, appear to influence drainage patterns in the area, with most drainages in the southern two-thirds of Quay County trending to the northeast (e.g., Plaza Larga, Barranca Creek, Trujillo Creek).

The Bonita fault zone is the best studied structure in east-central New Mexico (e.g., Stearns, 1972; Lucas et al., 2000), but there are also several faults in the area that have been overlooked. The most prominent of these is on the western side of Tucumcari Mountain, where the Mesozoic sequence drops approximately 150 m within 0.4 km. 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 part of the city near Tucumcari Elementary School, whereas the Chinle Group is exposed in the eastern part of the city near Tucumcari Lake. Therefore, the structure must be northerly in strike and located about a third of a mile from the western boundary of 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" that dropped the Chinle Group about 150 m. 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 likely that the structure on the western side of Tucumcari Mountain is a fault.

Dolliver (1985) demonstrated the presence of a fault underlying Plaza Larga, north of Mesa Redonda. Smaller, unmapped faults occur in the area, such as between Circle S Mesa and Pyramid Mountain, where the drag on the fault gives the illusion of an angular unconformity between the Redonda Formation and the Entrada Sandstone.

The most precise age for the Tucumcari structural zone can be derived from the Bonita fault zone. These faults cut through the Upper Cretaceous Bridge Creek Member of the Greenhorn Limestone, which is as young as earliest Turonian (Lucas et al., 2000), but they do not disrupt the Miocene Ogallala Group (Formation). Elsewhere in east-central New Mexico, there is an unconformity between the late Albian Pajarito Formation and the Ogallala Group that is never deformed, and in these areas the structures can be less precisely dated. However, it is clear that all the structures in the Tucumcari structural zone postdate the Turonian Late Cretaceous and predate the Neogene. This age, together with their northeasterly trend, suggests that they are most likely related to the Laramide orogeny.

Are these structures Laramide reactivations of older features? Broadhead and King (1988, fig. 3) produced the most accurate structural map of the Precambrian basement in this area, which shows a number of northeast-trending faults between northwestern Curry County and Tucumcari that form a series of horsts and grabens. Activity on most of these faults had ceased by Early Permian time (Broadhead, 1984).

To the southeast of the Tucumcari structural zone is the southwest-northeast-trending Frio uplift that separates the Tucumcari basin from the Palo Duro basin, and to the northwest is the Sierra Grande uplift that also trends southwest-northeast (Broadhead, 1988, fig. 1). During the Laramide orogeny, the southeastern-dipping Pecos shelf formed in southeastern and east-central New Mexico (Kelley, 1971). It appears likely that the Laramide buckling in the Tucumcari structural zone was a result of this southeastern tilting affecting an area between two northeast-trending uplifts that had healed faults with a northeast trend. Broadhead (1984; Broadhead and King, 1988) and McKallip (1985) documented the reactivation of Paleozoic faults during the Laramide. Kelley (1971) mapped a number of northeast-trending buckles (folds and/or faults) across the Pecos slope in southeastern New Mexico that are presumably a crustal response to the same stress pattern in a more unconfined terrane.

5.3 To left, the cap of Liberty Mesa is Lower Cretaceous Mesa Rica Sandstone overlying Lower Cretaceous Tucumcari Formation and Upper Jurassic Morrison Formation. **0.7**

6.0 San Miguel County line. San Miguel County was named by the Republic of Mexico in 1844 for San Miguel del Bado, one of the oldest communities in the area. It was the county seat until 1864, when the seat was moved to Las Vegas (Julyan, 1996). **0.3**

6.3 Historical marker for Fort Bascom (1863-1870), built to protect the area from Kiowa and Comanche Indians and to encourage settlement of the Canadian River valley. The post was first known as Camp Easton, after Major Langdon C. Easton of the Quatermaster's Department. The name was changed in January 1864 in honor of Captain George N. Bascom, who was killed at the Battle of Valverde, near Socorro. Fort Bascom was located in a horseshoe bend of the Canadian River, but the garrison of 88 men proved ineffectual, and the post was closed in 1870 and the troops transferred to Fort Union. A civilian settlement sprang up with a post office, but this was subsequently abandoned after changing its name to Johnson (Julyan, 1996).

Note Carpenter Mesa to right at 2:00 with prominent white sandstone near its top. This sandstone is similar to the Upper Jurassic Jackpile Member of the Morrison Formation (Holbrook et al., 1987) and is overlain by the Lower Cretaceous Tucumcari Formation and Mesa Rica Sandstone. The Brushy Basin Member of the Morrison Formation contains dinosaur fossils in this valley, including a complete sauropod ("brontosaur") femur. **2.2**

8.5 Cross canal. Note the low hills to the north of Mesa Rica Sandstone, which are much lower topographically than the same beds on the Canadian escarpment to the north. Again, this displacement reflects



FIGURE 3.2. The flank of Liberty Mesa from mile 8.9. Sandstone cliffs of the Cretaceous Mesa Rica sandstone cap the mesa above slopes developed primarily in the Upper Jurassic Morrison Formation.

Laramide structure. **0.4**

8.9 Road descends from eolian sand-covered bench, note red Chinle badlands ahead and Lower Cretaceous Mesa Rica Sandstone overlying Tucumcari Formation and Upper Jurassic Morrison Formation to left on mesa flanks, from 9:00-11:00 (Fig. 3.2). **0.3**

9.2 Cross swale. Note Upper Triassic Redonda Formation red-beds to left.

Francisco Vazquez de Coronado was dreaming of fame and fortune as he led his soldiers across eastern New Mexico in the Spring of 1541. A plains Indian, whom the Spaniards called El Turco (the Turk), was leading Coronado to the kingdom of Quivira. In Quivira even ordinary folk used silver spoons and golden bowls.

Coronado did achieve fame, but not for getting rich, rather for *not* getting rich. Coronado had a knack for *not* finding cities of gold. The previous year Coronado had found the mythical seven cities of Cibola, which turned out to be adobe pueblos of the Zunis. Quivira was no more promising -- it turned out to be villages of the Wichitas in Kansas built of sticks, not gold.

A minor part of Coronado's fame rests on his encounter with the North American bison (or buffalo). Coronado's men first encountered bison in the Canadian River Valley of eastern New Mexico, and they continued to see them as they journeyed into Kansas. It is difficult to imagine the impact of the first sight of these magnificent animals. Capt. Hernando de Alvarado, one of Coronado's assistants, had seen bison the year before and he described them as "the most monstrous beasts we have ever seen or heard about." They were so numerous that he "did not know to what to compare them unless it be to the fish of the sea." Coronado's encounter with the bison in 1541 was not forgotten. Ninety years later, in 1651, Sr. Hernandez, who had never actually seen a bison, described this animal based on descriptions of the "cattle of the Quivira region" written by various members of Coronado's expedition (see accompanying minipaper).

Coronado met Apaches in 1541 who were hunting bison. Bison provided not only meat but also many of the other basics of life such as clothing. The Spaniards may have been acknowledging the importance of the bison when they called them "cibolo," which is from the same word source as "cibola," which they used for the mythical golden cities. **0.3**

THE TYPE AREA OF *BISON BISON* (LINNAEUS, 1758), CANADIAN RIVER VALLEY, EAST-CENTRAL NEW MEXICO

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Linnaeus (1758) recognized two species of bison in his tenth edition of *Systema Naturae* — the American bison as *Bos bison* and the European wisent as *Bos bonasus* — although he had previously listed them in the sixth edition (Thomas, 1911; McDonald, 1981). Because the American bison was described in 1651 by Hernandez (Fig. 3.3), and the European species was described in 1693 by Ray, the type species of the genus is the American *B. bison*. Subsequently, Bojanus (1827) placed extinct bison in the genus *Urus*, Smith (1827) utilized *Bison* as a subgenus and Knight (1849) accorded *Bison* generic rank (McDonald, 1981). Now the species *bison* and *bonasus* are placed within the genus *Bison* together with other species, and with *B. bison* as the type species.

According to the *International Code of Zoological Nomenclature*, every nominal taxon has, "actually or potentially," a name-bearing type specimen. In the case of *Bison bison* there is no actual type specimen because Linnaeus (1758) named the taxon based on a description published by Hernandez (1651), who in turn had never actually seen a bison! Hernandez (1651) based his description on the writings of members of Francisco Vazquez de Coronado's expedition, which passed through eastern New Mexico in the Spring of 1541.

Hernandez (1651) explicitly stated that his description of the American bison was based on descriptions of "cattle of the Quivira region" by members of Coronado's expedition even though other eyewitness accounts of these animals were available to him (Reed, 1952, 1955; Brand, 1967; McDonald, 1981). Given the lack of a type specimen of *Bison bison*, it is important to locate

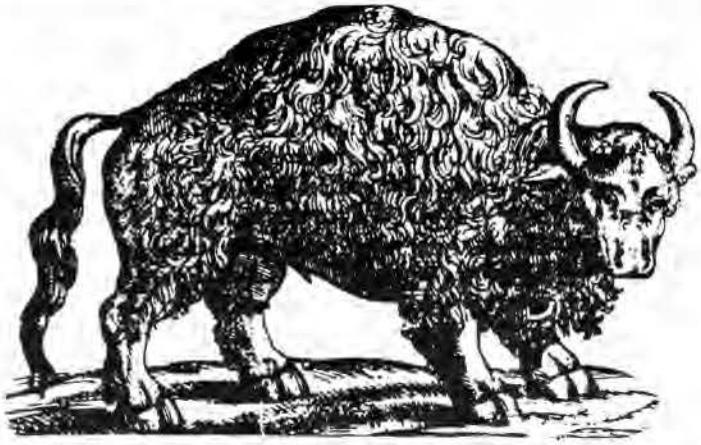


FIGURE 3.3. Dr. Francisco Henandez' 1651 illustration of the Mexican bull, "*Taurus mexicanus*," which Linnaeus (1758) used as the basis for his *Bos bison*, now *Bison bison* (after McDonald, 1981).

the type locality for this species, from which a neotype specimen might be collected. The type locality is the area where bison were encountered and described by Coronado's expedition and thus formed the basis of Hernandez' (1651) description and Linnaeus' (1758) naming of the species. Four authors have discussed the search for the type area of *B. bison*.

1. Thomas (1911) identified Mexico as the type area for *B. bison*, with the recognition that seventeenth century Mexico included much of the southwestern United States.

2. Reed (1952, 1955) identified the southern or southeastern United States as the type area because this was where Europeans first saw bison.

3. Hershkovitz (1957) reasoned that because Hernandez (1651) had explicitly based his description on animals of the Quivira region, that the type area should be in central Kansas, which is where the Quivira villages were located.

4. McDonald (1981) noted that Quivira could not be considered the type locality. The main force of Coronado's expedition first saw bison in the Canadian River Valley of east-central New Mexico and then encountered them until the force was split into two units in West Texas. One unit headed north to Quivira, where they reported seeing bison until they were within three or four days of the Quivira villages. In the next month in the Quivira region they did not see, or at least did not report seeing, any bison. Therefore, McDonald (1981, p. 62) concluded "considering the Coronado expedition's experience with bison, and accepting the reports of members of Hernandez' information on *B. bison*, the type locality is here designated as the Canadian River Valley of eastern New Mexico."

Given the geography of the Canadian River area, it is clear that the type area of *Bison bison* can be further restricted to eastern San Miguel County or Quay County, New Mexico. Due to the distribution of open range land, it is most likely that bison would be encountered in the plains of Quay County as opposed to the canyon country to the west. Therefore, in conclusion, it is most likely that the type area for *B. bison* is in Quay County, New Mexico.

9.5 Road descends to cross creek. Note well-exposed Redonda Formation calcretes and siltstones. Canadian River and associated bosque visible at 2:00, with Carpenter Mesa in the distance behind them. In this area, there are a series of northwest-southeast-trending anticlines with low dips along the northwestern boundary of the Tucumcari structural zone.

The Canadian River has a couple of very unusual characteristics. Its headwaters are in the Sangre de Cristo Mountains of Colorado and New Mexico from whence it flows almost due south, but at Conchas Lake it takes an abrupt 90° turn to the east. Also, on the Harding and Mora County boundary, the Canadian is entrenched in a 150-m deep canyon, whereas here the river lies in a broad floodplain. The strange bend in the river is the result of the capture of east-flowing tributaries of the Canadian by the Pecos River during the middle Pleistocene, and the incision occurred mainly in the late Pliocene-early Pleistocene as a result of epeirogenic uplift and climatic changes (Dolliver, 1984). **0.1**

9.6 Cross Road Creek tributary. **0.5**

10.1 Red-beds adjacent to the road are Upper Triassic Bull Canyon Formation. Look left to see unconformable contact between the Bull Canyon Formation and the overlying Redonda Formation. Road drops into the Bull Canyon Formation. **0.3**

10.4 Cross another tributary of Road Creek. Badlands for next mile on left and right are developed in Bull Canyon Formation. **1.0**

11.4 Crest alluvium-capped ridge. **0.6**

12.0 At 3:00, note salmon-colored, ribbed cliffs on point of mesa. These are strata of the Jurassic Summerville Formation (= type Bell Ranch Formation). The terms Bell Ranch Formation (Griggs and Read, 1959) and "lower member" of the Morrison Formation (e.g., Wanek, 1962; Trauger and Bushman, 1964) were long used to refer to strata in east-central New Mexico properly called Summerville Formation (Anderson and Lucas, 1992; Lucas and Anderson, 1998). These strata occupy the same stratigraphic position and are remarkably similar to Summerville strata farther west. Thus, Summerville strata in east-central New Mexico are as much as 30 m thick and consist of thinly and repetitively bedded, fine-grained sandstone, gypsum, siltstone and sandy mudstone. **0.8**

12.8 At 10:00, Middle Jurassic Entrada Sandstone crops out as tan sandstone overlying Upper Triassic Redonda Formation. **0.6**

13.4 Ledges of ripple-bedded Upper Triassic Redonda Formation on left. **0.9**

14.3 Mesa Rica at 9:30-12:00 to left of highway. Mesa Rica (Spanish for "rich mesa") is said to have been named for the treasure of a group of '49er's returning from California who were massacred by Indians, or possibly for a gold-bearing burro train that met a similar fate. In either case, the loot was hidden on the mesa and has yet to be found (Julyan, 1996). **1.2**

15.5 Cross Johnson Creek. Note gentle fold in Mesa Rica Sandstone on mesa to north, another Laramide structure. **2.3**

17.8 For the next 0.4 mi, excellent red-bed exposures, with prominent eolian sandstones on right, just below road are Upper Triassic Redonda Formation. **0.7**

18.3 **STOP 1. Pull over and park on right side of road.** This stop affords us a close examination of an unusual lithofacies of the Redonda Formation--massive, laterally continuous sandstone--and our discussion is based largely on Hester (1988). This sandstone lithofacies (Fig. 3.4) is composed of very fine to medium grained, moderately sorted sand with minor amounts of coarse sand and occasional wood fragments. Vertical and sub- horizontal *Scoyenia gracilis* burrows are sometimes present in the otherwise structureless sandstones.

These sandstones occur as laterally continuous, 40 cm to 13 m thick, single bed units, although average thickness is 1.5 m. Some sandstone beds persist at the same stratigraphic level for as much as 24 km. Lower contacts are irregular due to load casts, but spheroidal weathering accentuates the irregularity. Locally, small (2-3 cm wide, 10-100 cm long) sandstone dikes may taper downward and branch or be of consistent thickness as they project down into underlying mudstones. Upper contacts are sharp. Burrows on the upper surface are filled with overlying mudstone.

Lack of traction structures within these sandstones could be attributed to: (1) destruction of primary bedforms by organisms, (2) homogeneity of sand, or (3) deposition where currents or waves did not affect sediments. The well-preserved, distinctive character of the burrows, rather than a totally bioturbated fabric, rules out the first possibility. Although not abundant, the occurrence of some coarser material indicates transport energy sufficient to carry coarse sand. Wood fragments might float until they became waterlogged and sunk. Once deposition took place, this coarser material was not reworked into traction structures, suggesting that once deposited, massive sandstones were not influenced by moving water.



FIGURE 3.4. Hammer rests on massive sandstone lithofacies of the Upper Triassic Redonda Formation at Stop 1.

The overall environment of deposition of the Redonda Formation was lacustrine (Hester, 1988). Coarse materials can be carried into deep lake waters by river plumes (under-,inter-, and overflows), turbidity, or slumping processes. If episodic turbidity currents deposited these sands, some traction structures would be expected. Slumps would generate structures indicative of rapid deposition such as dewatering structures, but homogeniety of the sand and fine grain size might obscure such bedforms. Density flows from rivers transport fine sand and silt into a basin on a continuous basis. This massive sandstone lithofacies of the Redonda Formation thus contains evidence of continuous deposition (bioturbation), but lack of other structures make the process that transported these sands difficult to identify.

After stop continue west on highway. 0.9

19.2 Old road to abandoned rest area comes in from left. This area is known locally as "The Narrows." **0.3**

19.5 **STOP 2.** Pull off on right after crossing small creek. Middle Jurassic Entrada Sandstone well-exposed in road cuts with bouldery alluvium above (Fig. 3.5). Note the Upper Triassic Redonda Formation-Middle Jurassic Entrada Sandstone contact on right side of the road. The uppermost Redonda bed is moderate reddish brown, silty, very fine-grained calcareous litharenite, whereas the basal Entrada bed is moderate orange-pink, fine-grained calcareous subarkose.



FIGURE 3.5. The Middle Jurassic Entrada Sandstone at Stop 2. A, Overview of Entrada roadcut. B, Close-up of eolian foresets.

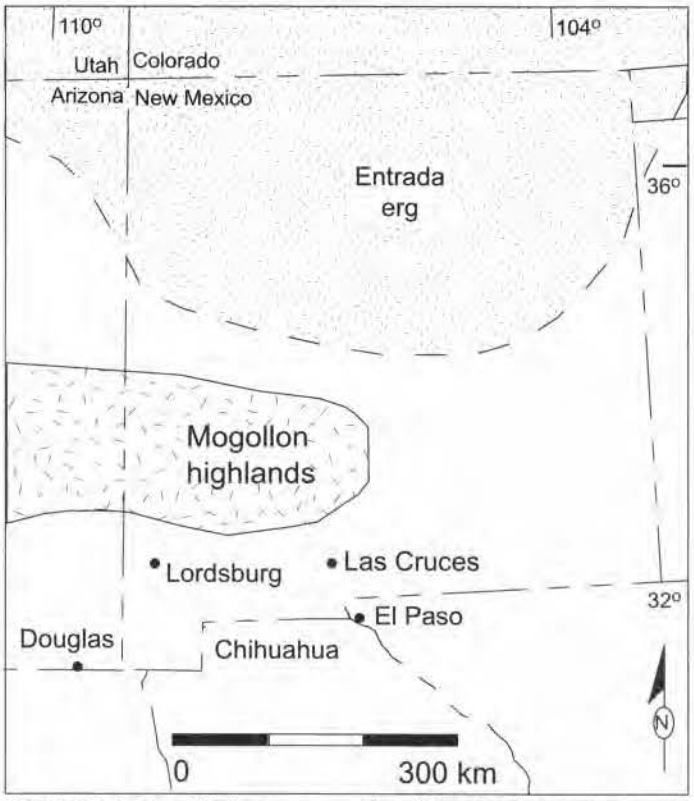


FIGURE 3.6. Simplified paleogeography of New Mexico during Entrada deposition.

The Entrada Sandstone accumulated in a vast sand sea (erg) in the American Southwest during the Middle Jurassic (Bathonian-Callovian) (e.g., Kocurek and Dott, 1983; Blakey et al., 1988; Lucas and Anderson, 1997). This erg covered parts of eastern Utah, southern Wyoming, northeastern Arizona, much of Colorado, northern New Mexico and western Oklahoma (Fig. 3.6). Eolian deposition of the Entrada is inferred from its fine- to medium-grained, well-sorted, subrounded sand grains, which typically display large scale trough crossbeds. Crossbed azimuths indicate regional paleocurrent (wind) direction to the south and southwest (Poole, 1962; Blakey et al., 1988).

This Entrada outcrop here is significant for three reasons:

1. It preserves only dunal and interdunal facies of the upper member of the Entrada Sandstone, the Slick Rock Member. These are characteristic deposits of the vast Entrada erg.

2. Paleocurrent azimuths (foreset dips) here are to the east (Fig. 3.7), which is somewhat anomalous for the regional paleowind patterns.

3. The absence of the lower, Dewey Bridge Member here, and across eastern New Mexico, means we are landward of the Carmel transgression. The Dewey Bridge Member is the paralic facies of the Carmel seaway, which transgressed into central Utah during the Bajocian-Bathonian. In New Mexico, the easternmost outcrops of the Dewey Bridge Member are at Placitas and in the Hagan basin of north-central New Mexico (Lucas et al., 1995; Anderson and Lucas, 2000). This is thus the easternmost extent of the paralic facies of the Carmel seaway

After stop continue west on highway. 0.7

20.2 Crest rise; note Mesa Rica is ahead south of the highway. **1.1**

21.3 Currently driving on Middle Jurassic Entrada Sandstone bench. Note at 10:00 that Summerville Formation forms a ribbed slope overlying the Entrada. **0.2**

21.5 Descend into Upper Triassic Redonda Formation. Note contact of Bull Canyon and Redonda forma-

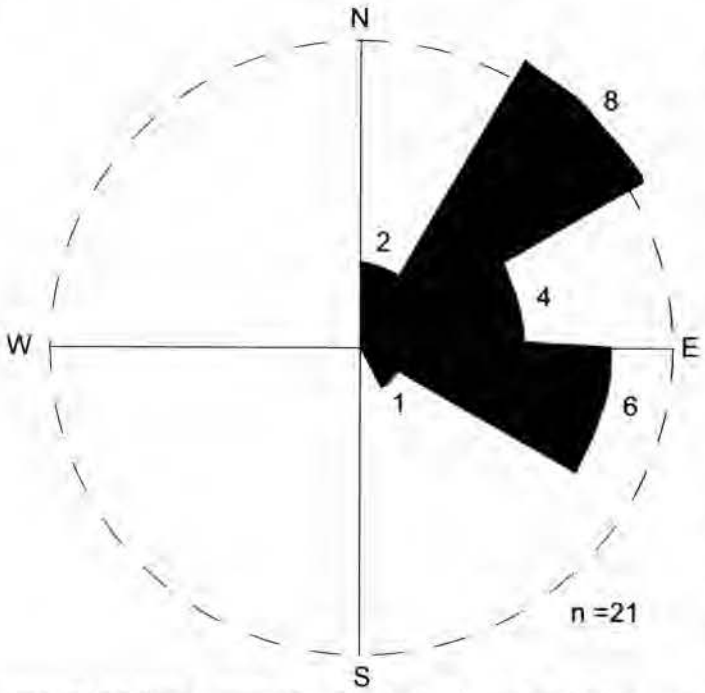


FIGURE 3.7 Rose diagram of crossbed azimuths in Entrada Sandstone at Stop 2.

tions on right. The calcrete that is well exposed on the left side of the road is the basal unit of the Redonda Formation. Note the differences between the two units in the outcrops to the right of the road as we descend the hill. The Bull Canyon Formation has a more brick-red color, and contains more mudstones and lenticular sandstones. **0.8**

22.3 Cross Alamosa Creek. **0.9**

23.2 Crest ridge; to the north (right) the lower breaks are developed in the Upper Triassic Bull Canyon Formation. Beyond, cliffs of Carpenter Mesa are red-ribbed Upper Triassic Redonda Formation overlain by salmon-colored Middle Jurassic Entrada Sandstone and Summerville Formation under a slope of Jurassic Morrison Formation capped by the Cretaceous Mesa Rica Sandstone. **1.5**

24.7 Cross Corralitos Creek; badlands up creek and along the road for the next mile are Upper Triassic Bull Canyon Formation. **2.5**

27.2 Crest low ridge. Note low badlands developed in Upper Triassic Bull Canyon Formation to right in front of Jurassic-Cretaceous section on Carpenter Mesa. Outcrops in this area have yielded fragmentary remains of Triassic reptiles, including numerous teeth of phytosaurs and dinosaurs. **1.3**

28.5 Cross creek. Sandstone exposed in the floor of the creek bed may be the top of the Upper Triassic Trujillo Formation. **0.9**

29.4 Butte at 9:30 is made up of red-bed Upper Triassic Bull Canyon Formation. **0.9**

30.3 Enter greater Conchas Dam metropolitan area. **0.6**

30.9 Junction with NM-433. **Turn right to Conchas Dam State Park**. **0.3**

CONCHAS AND UTE RESERVOIRS AND WATER ISSUES IN EASTERN NEW MEXICO

Adrian P. Hunt

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The history of dammed reservoirs in eastern New Mexico dates back to 1912 to the design of the first Tucumcari Irrigation Project, which would, if completed, have involved the construction of two dams on Pajarito Creek. In 1925, the Canadian River Development Association was formed to push for a reliable source of irrigation water in east-central New Mexico. After many years of lobbying, Congress passed the Flood Control Act in 1936 that authorized and appropriated funds for the construction of Conchas Dam. In 1937, the New Mexico Legislature approved the formation of the Arch Hurley Conservancy District. The Corps of Engineers finished Conchas Dam in 1939, which was the flood control portion of the project, and by 1954 the Bureau of Reclamation had completed the irrigation component of the project (Geyler, 1998). The total capacity of Conchas Dam is 318,000 acre-feet at spillway crest elevation, but about 68,000 is inactive storage below the invert elevation of Conchas Canal (Mutz, 1998).

The Arch Hurley Conservancy District utilizes approximately 40 mi of main canals and 350 mi of smaller ditches and laterals to deliver 1.33 acre feet of water to 42,000 acres of land. However, while yields from irrigated lands are greatly elevated, the irrigation is used to produce the same crops grown on a "dryland" basis on adjacent acreage, so the full potential of the project has yet to be realized (Geyler, 1998).

The Entrada Sandstone aquifer west of Tucumcari has remained essentially stable since 1943 (Wilson, 1998). However, this aquifer has been recharged by leakage from the Arch Hurley canal, and proposals to line the canal fully could adversely effect this aquifer, which provides all of the water for the city of Tucumcari.

Ute Dam and Reservoir were authorized by the New Mexico State Legislature in 1957, and the initial stage of construction was completed in 1962, with a total capacity at spillway crest elevation of about 110,000 acre-feet. In 1975-1981, the New Mexico State Legislature authorized funding for additional construction to increase the reservoir capacity. By 1984, the expansion was completed, and the capacity increased to 272,000 acre-feet. This increase in size resulted in a lawsuit by the states of Texas and Oklahoma over the terms of the Canadian River Compact of 1950. This suit was settled by the United States Supreme Court, utilizing a Special Master, in 1993 (Mutz, 1998).

Two multi-million dollar projects will result from the construction of Ute Dam. The first is due to a problem at Lake Meredith northeast of Amarillo, which provides a major portion of that

urban area's municipal and industrial water. Lake Meredith has chloride levels as high as 350-450 mg/l as a result of the inflow of natural brines into the Canadian River in a six-mile stretch from Ute Reservoir to Revuelto Creek. The brine originates from the dissolution of Permian salts that flow upward from an artesian brine aquifer in the lower Chinle Group. Many factors influence the location and rates of inflow into the Canadian River, but there is strong evidence that the enlargement of Ute Reservoir increased the rate of groundwater brine inflow. Two projects aim to alleviate the chloride problem. First, there will be a large well field in an undeveloped portion of the Ogallala aquifer in Roberts County, Texas that will provide low chloride waters to be blended with those from Lake Meredith. Second, there is the Lake Meredith Salinity Control Project, which involves the drilling of 11 wells near Logan to depths of 120 to 260 ft. Brine from these wells will be transferred by a buried pipeline south of the river to a facility where the water will be injected 3100 feet down into Paleozoic strata. This project is a cooperative effort of the Bureau of Reclamation, the Canadian River Municipal Water Authority and the Texas Water Development Board and will cost about $9.5 million (Wilson and Esparza, 1998).

Wilson and Esparza (1998) detail the Lake Meredith Salinity Control Project and demonstrate that it is utilizing unconventional stratigraphic nomenclature. First, they interpret the Triassic sequence in the Ute Dam area to be Trujillo Sandstone of the Santa Rosa Formation overlying the Tecovas Sandstone of the Santa Rosa Formation. In fact, the bedrock around the dam is more properly considered the Trujillo Formation of the Chinle Group. The Trujillo has never been a member of the Santa Rosa Formation. The Tecovas Formation is not present in New Mexico, and has never been considered a member of the Santa Rosa Formation. The mudstone-dominated Garita Creek Formation underlies the Trujillo Formation, and it is likely that the "Tecovas" is actually the lower Trujillo Formation. Wilson and Esparza (1998, fig. 4) show the Trujillo separated from the "Tecovas" by a "confining shale." It is likely that this is just one of many mudstone intervals within the Trujillo Formation. Also, Wilson and Esparza (1998) note that the brine will be injected into the Pennsylvanian Sangre de Cristo Formation. This unit is not present in the subsurface of the Tucumcari basin (Broadhead and King, 1988), and it is likely that the unit in question is the Permian Abo Formation.

A second major project involving Ute Reservoir is the eastern New Mexico Water Supply Project that has been known by a number of names over 40 years and whose aim is to deliver water from Ute Reservoir to communities in east-central and southeastern New Mexico (Martinez, 1998). This is especially important given the alarming (but predicted) depletion of the Ogallala aquifer, which has a lifetime of from 33 years in Curry County to 40 years in Union County (Wilson, 1998). In 1983, the City of Tucumcari contracted with the Interstate Stream Commission for 3400 acre-feet. Subsequently, in 1987, the Ute Water Commission was formed and involved county commissions from Quay, Curry and Roosevelt counties as well as major and minor communities in these counties. The commission is actually a joint powers agreement entity allowing a sharing of authority among local jurisdictions and the Eastern Plains Council of Governments. In 1987, the United States Congress appropriated $300,000 for an engineering study of the Quay County portion of a proposed pipeline that would go south from Ute Lake to Roosevelt County. Ute Lake's total yield is estimated to be 24,000 acre-feet. Current estimates by Smith Engineering put the total cost of the project, involving a pipeline from Ute Lake as far south as Elida, and including the daunting prospect of raising water up the Llano Estacado, at $212 million with 90% paid by state and federal sources.

At the time of writing (January 2001) the Ute pipeline project is mired in acrimony. Logan threatens lawsuits because of the economic impact on tourism of lowered lake levels. Quay County is considering its own pipeline at an estimated cost of $8-10 million, principally because a shared pipeline to Clovis and Portales would be too large (and expensive) to accommodate peak demand in these urban areas. Tucumcari currently reserves rights to one quarter of the water reserved by the commission, but under the full plan this would cost this small community $2.5 million per year for 20 years. Two things are clear: (1) the Ogallala aquifer is near the end of its life, and the High Plains communities are going to need to find their water somewhere else, so Tucumcari may face a depleted aquifer; and (2) if by 2006, the Ute Water Commission does not implement a plan, other entities such as the City of Albuquerque will most assuredly buy the Ute water rights.

31.2 Lodge Road intersection. **Continue straight. 0.1**

31.3 Road forks, **stay right**, going north by dam. **0.5**

31.8 Parking area and information sign to right; note sandstones of Upper Triassic Trujillo Formation over mudstones of Upper Triassic Garita Creek Formation in slope to right. An incomplete phytosaur jaw was collected from these Garita Creek outcrops. **0.2**

32.0 Trujillo roadcuts to right, Dam to left. **0.8**

32.8 Intersection with road to Conchas recreation area, **continue straight. 0.8**

33.6 Drive along crest of dam, **turn hard right and proceed into parking lot. 0.1**

33.7 **STOP 3.** Conchas Dam (Fig. 3.8). For information on Conchas Dam and the State Park see the accompanying minipaper. The bedrock exposed at Conchas Dam is the lowest strata of the Upper Triassic Chinle Group, the Santa Rosa Formation (Fig. 3.9). In east-central New Mexico, the Santa Rosa Formation consists of three members. The basal Tecolotito Member is up to 104 ft thick and is mostly grayish orange, trough-crossbedded and ripple-laminated quartzarenite. The overlying Los Esteros Member is as much as 134 ft thick and consists of yellow and reddish brown mudstone with minor quartzarenite. The Tres Lagunas Member is up to 140 ft thick and is composed of orange and yellowish brown, crossbedded quartzarenite.

Conchas Dam is anchored in the sandstone-dom-



FIGURE 3.8. Construction of Conchas Dam in 1939 (courtesy of Musem of New Mexico, negative 59160).

inated Santa Rosa Formation, and when the dam was built these strata were informally termed the "canyon sandstone" (e.g., Matthes, 1936). Spiegel (1972) correlated this sandstone interval to the Trujillo Formation of West Texas, which is in the middle of the Chinle Group, but other workers (e.g., Griggs and Hendrickson, 1951; Wanek, 1962; Dane and Bachman, 1965; Kelley, 1972; Lucas et al., 1985a) have assigned it to the Santa Rosa Formation. Recently Fritz (1991, p. 110), in a regional study of the Santa Rosa Formation, concluded "it is not possible to determine whether or not the 'canyon sandstone' represents a member of the Santa Rosa Formation."

Actually, all three members of the Santa Rosa Formation named by Lucas and Hunt (1987) make up the "canyon sandstone." A detailed measured section on the north bank of the river, at the point just downstream of Conchas Dam, makes this clear (Fig. 3.9):

1. The top of the section, the strata on which we are standing, are 10 ft or more of red-bed mudstones, siltstones and ripple-laminated sandstones at the base of the Upper Triassic Garita Creek Formation. Tetrapod footprints are present in these strata (see accompanying minipaper).

2. The underlying cliff is grayish orange and pale yellowish brown sandstones that are trough-crossbedded and ripple-laminated quartzarenites above a 7-ft-thick calcrete-pebble conglomerate. These strata are ~30 ft thick and are readily assigned to the Tres Laguna Member of the Santa Rosa Formation.

3. These strata overlie ~40 ft of red-bed mudstone and pale reddish brown, very fine grained, ripple-laminated sandstone that belong to the Los

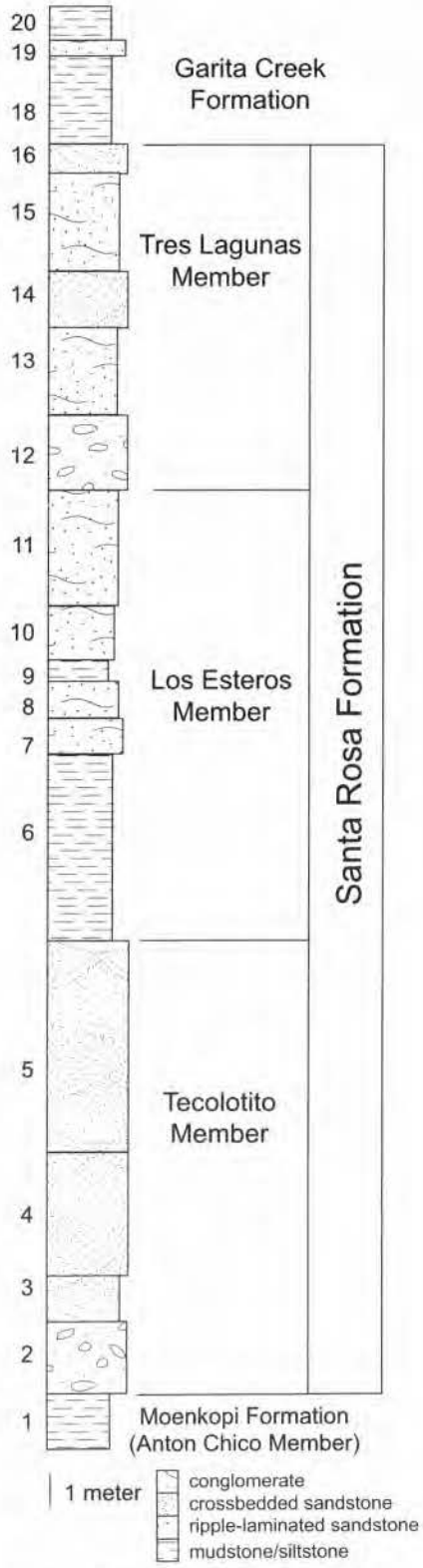


FIGURE 3.9. Measured stratigraphic section of Santa Rosa Formation at Conchas Dam. See Lucas et al. (this guidebook) for a more detailed description of this section.

Esteros Member of the Santa Rosa Formation.

4. Underlying sandstones are pale yellowish brown, trough-crossbedded quartzarenites above a distinctive extraformational conglomerate (Fig. 3.10). Clasts in this conglomerate are extrabasinal lithics, Paleozoic limestones and quartzites up to 6 inches in diameter. This is the extrabasinal conglomerate characteristic of the base of the Chinle Group throughout the western United States (Lucas, 1993). This basal sandstone and conglomerate interval, ~40 ft thick, is thus the Tecolotito Member of the Santa Rosa Formation.

5. Just above river level, the base of the exposed section is pale reddish brown mudstones and siltstones of the Anton Chico Member of the Moenkopi Formation.

After stop proceed out of parking lot. 0.1



FIGURE 3.10. Basal, extraformational conglomerate of Tecolotito Member of Santa Rosa Formation at Conchas Dam.

THE FIRST VERTEBRATE TRACK (*BRACHYCHIROTHERIUM*) FROM THE UPPER CARNIAN GARITA CREEK FORMATION, EAST-CENTRAL NEW MEXICO

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Late Triassic vertebrate tracks in eastern New Mexico are restricted to the Norian Bull Canyon and Redonda formations (Hunt et al., 1993). Here, we report on the first late Carnian tracks, from the Garita Creek Formation. The Garita Creek has otherwise yielded a vertebrate body-fossil assemblage that is of Adamanian (late Carnian) age (Hunt et al., 1989; Hunt and Lucas, 1993).

The tracks are preserved in a 0.4-m thick bed of ripple-laminated and mudcracked, pale reddish brown, fine-grained micaceous litharenite sandstone about 2.5 m above the top of the Santa Rosa Formation. A single *in situ* slab preserves a partial trackway of a quadrupedal tetrapod. One pedal and manual pair of tracks are preserved well enough to be identified (Fig. 3.11). The tracks are preserved in convex hyporelief. The pes impression is 130 mm long and 108 mm wide. There is a well-developed posteromedially-directed posterior extension of the track, giving an over-



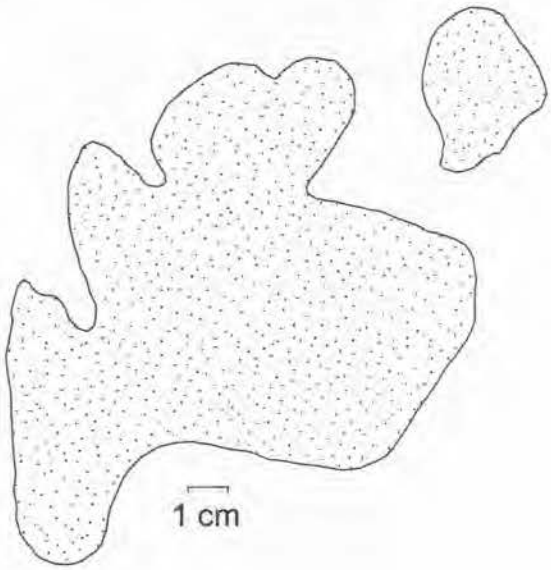


FIGURE 3.11. Track of *Brachychirotherium* in Garita Creek Formation at Conchas Dam.

all L-shape to the pes impression. There is a distinct posterolateral digit impression that is oriented anterolaterally. Anterolaterally, there are the impressions of an additional three, rounded digits. The manus impression is ovoid in shape, with a maximum length and width of 37 mm and 32 mm, respectively. It is located anterior to the midline of the pes impression. There is a second, very poorly preserved pes impression on the slab with a pace of 31 cm. The trackway is trending 242°.

The vertebrate ichnofauna of the Chinle Group of western North America has been well-studied (e.g., Conrad et al., 1987; Hunt et al., 1993; Lockley and Hunt, 1999). There is only one known large (pedal length >100 mm) quadrupedal tracktype with a marked disparity between the size of the pes and manus impressions, and that is *Brachychirotherium*. Further, the lateral direction of the pes digit impressions distinguishes the Garita Creek track from other known Late Triassic tracks that have large pes impressions and small manus imprints, such as *Apatopus* and *Atreipus* (e.g., Baird, 1957; Olsen and Baird, 1986). The narrow gait of the Garita Creek specimens is also consistent with that of *Brachychirotherium* (e.g., Lockley et al., 1987, fig. 5A). Thus, we consider it most parsimonious to assign the Garita Creek track to *Brachychirotherium*. *Brachychirotherium* is conventionally considered to be the track of a derived crurotarsan such as an aetosaur.

This occurrence is the first of a tetrapod track from the Garita Creek Formation and the first from the late Carnian of eastern New Mexico. Indeed, the majority of the tracks known from the Chinle Group are from the uppermost Norian (Apachean) strata in Colorado, Utah, Arizona and New Mexico (Hunt and Lucas, 1992). Only three late Carnian tetrapod tracksites are known from Adamanian strata of western North America, compared to more than 60 from the Apachean (Santucci et al., 1994; Lockley and Hunt, 1999).

CONCHAS LAKE STATE PARK

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Conchas Lake State Park (Fig. 3.12) was established in 1955 and named after the Conchas River, one of the tributaries of the Canadian River. Conchas is Spanish for shells and was applied to a group of Indians living in the area when seventeenth century Spanish explorers arrived. The word conchas also may be a corrupted name that is confused with the Spanish word conchos, a term also used to describe the Native American tribes in northern New Mexico (Julyan, 1996).

The dam that formed Conchas Lake was the seventeenth dam in the country built by the U. S. Army Corps of Engineers (Young, 1984). It is one of the state's oldest dams, completed in 1939 to control floods, store water for irrigation and local supplies, and assist in local economic recovery from the Depression (Welsh, 1985). More than 3000 people were employed to build the dam. The structure is a concrete and earthen dam that is 235 ft high and 1250 ft long. The lake has a reservoir capacity of 528,951 acre feet of water and sediment. It extends 14 mi upstream of the Canadian River and 11 mi upstream of the Conchas River. The total cost of land purchases, construction and maintenance amounted to nearly $15.8 million (Young, 1984; Welsh, 1985). Water from the lake is used to irrigate 41,400 acres of farmland of the Tucumcari Irrigation Project and travels through 300 mi of canals and laterals.

Conchas Lake State Park ranges in elevation from 4150 to 4250 ft above sea level and occupies 1160 acres of land and 9000 acres of water (surface). Only three sites are administered by the State Parks Department (Northside, Central, and South); most of the land surrounding Conchas Lake is private (Fig. 3.12). The U. S. Army Corps of Engineers administers a day-use site and a visitor's center (open on weekdays). All of the water is open to the public. Sandy beaches are separated by rocky beaches and offer a diversity of opportunities appreciated by both swimmers and fisherman. Coves abound and provide solitude, even during busy holiday weekends.

Recreational activities include hiking, picnicking, camping, swimming, fishing, boating, sailing, scuba diving and water skiing. Camp and picnic sites are along the lake as well as along hills and mesas above water level. Launching ramps for boats and a marina are available. The State Park Office is located at the Northside Recreation Area. The State Department of Game and Fish stocks the lake with walleye pike, small- and large-mouth bass, catfish, crappie, bluegill and northern pike. A playground, golf course, lodge, seaplane landing area, paved airport and full restroom facilities with showers, water and electrical hookups are available. Scuba diving is popular. Cannon Air Force Base also has a small recreation area for military personnel.

Arrowheads, stone tools and pottery shards found throughout the area remind us that prehistoric man probably inhabited the area long ago. Arrowheads found in now extinct bison indicate that Folsom man, named for the town in Union County, lived north of Conchas Lake about 8000–10,000 years ago. Petroglyphs are found in sandstones along some of the bays and inlets of Conchas Lake and also testify to the presence of early inhabitants. Most of these early inhabitants were primarily hunters and gathers. A relic petroglyph in sandstone rests in a building near the Army Corps of Engineers administration building, north of the spillway. When the Spanish explored the area in the 1500s, the Ute, Comanche and Apache Indians called the area covered by Ute Lake and Logan their hunting grounds (Scott, 1986). The first Spaniard in the immediate area was probably Don Antonio de Valverde, who traveled along the Canadian River to Kansas in 1719, before Conchas Lake was formed (Scott, 1986).

Later, Spanish explorers settled in the area that was once part of the Pablo Montoya or Baca land grant. In 1867, John Watts acquired title to the Baca land grant and transferred it to Wilson Waddington in 1872. Waddington conveyed usage of the land to the Consolidated Land, Cattle and Wool Growing Co. This was the beginning of the Bell Ranch.

Most of the rocks surrounding Conchas Lake, including those that form the bedrock of the dam, belong to the Upper Triassic Chinle Group. The Chinle Group consists of alternating layers of red-brown to maroon to gray mudstone, siltstone and sandstone that were deposited in continental fluvial and lacustrine environ-

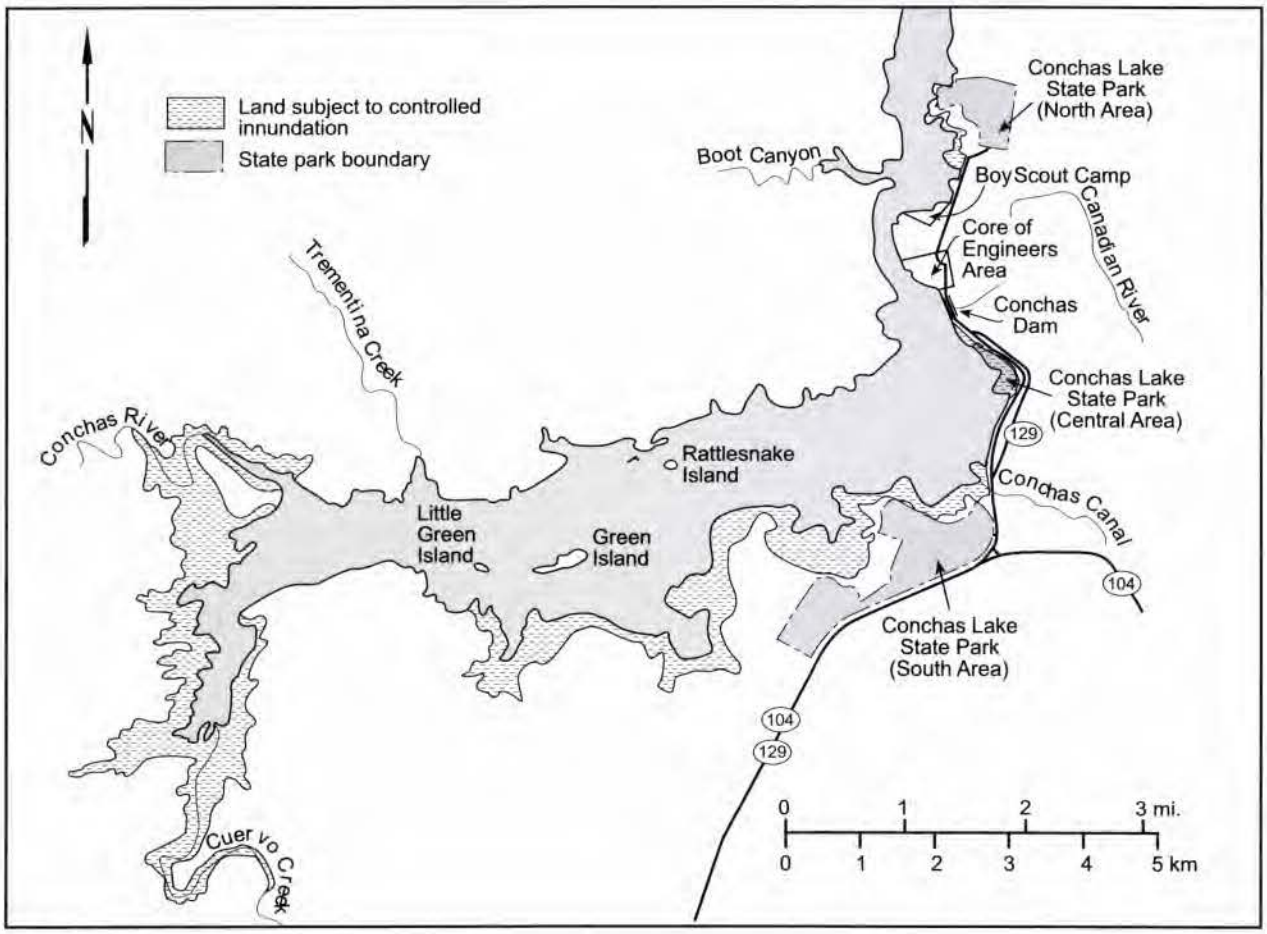


FIGURE 3.12. Map of Conchas Lake.

ments about 205-225 Ma. The Chinle Group is divided into five formations in eastern New Mexico (in ascending order): Santa Rosa, Garita Creek, Trujillo, Bull Canyon and Redonda formations (Lucas, 1995). The medium- to light-gray, massive to crossbedded sandstone exposed at the dam is the Santa Rosa Formation. The crossbeds in the sandstone are consistent with fluvial deposition. Mudcracks indicate that sometimes the sandstones were exposed to drying. The red color is produced by the oxidation of iron within the minerals forming the sandstone; this oxidation is common to seasonally arid environments such as existed at the time the Chinle was deposited. Sections of the core drilled and recovered during construction of the dam are on display near the Army Corps of Engineers administration building, north of the spillway.

Channel deposits of gravel and sand derived from the glaciated terrain in the Sangre de Cristo Mountains during the Pleistocene are found along the Canadian River above and below the dam (Spiegel, 1972). The Canadian River formed during the Pleistocene after the Wisconsinan glaciation (Dolliver, 1984). The headwaters are in the Rocky Mountains in Las Animas County, Colorado, northwest of Raton, New Mexico. The river flows southeastward from the headwaters to Raton, where it flows south to Conchas Lake State Park. At Conchas Lake the river flows due east to Ute Lake State Park and eastward into West Texas and Oklahoma. For most of the river's course in New Mexico, it is a sinuous meander belt that rarely exceeds 750 ft in width (Kessler, 1972). Floods since 1938 have eroded and degraded the river rather than deposit new stream deposits (Kessler, 1972).

33.8 **Turn right** at yield sign and cross dam. **0.4**

34.2 **Turn right** into picnic area for lunch. Note at the parking lot the large cylinders of Triassic sandstone from the coring done while constructing Conchas Dam.

End of Third-day Road Log.