The San Juan volcanic field and Cretaceous depositional systems: Third-day road log from Chama to Cumbres Pass, Los Brazos, and Heron Lake

Spencer G. Lucas, Andrew B. Heckert, Kate E. Zeigler, Donald E. Owen, Adrian P. Hunt, Brian S. Brister, Larry S. Crumpler, and Justin A. Spielmann

2005, pp. 57-68. https://doi.org/10.56577/FFC-56.57

in:

Geology of the Chama Basin, Lucas, Spencer G.; Zeigler, Kate E.; Lueth, Virgil W.; Owen, Donald E.; [eds.], New Mexico Geological Society 56th Annual Fall Field Conference Guidebook, 456 p. https://doi.org/10.56577/FFC-56

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

THE SAN JUAN VOLCANIC FIELD AND CRETACEOUS DEPOSITIONAL SYSTEMS

THIRD-DAY ROAD LOG FROM CHAMA TO CUMBRES PASS, LOS BRAZOS, AND HERON LAKE

SPENCER G. LUCAS, ANDREW B. HECKERT, KATE E. ZEIGLER, DONALD E. OWEN, ADRIAN P. HUNT, BRIAN S. BRISTER, LARRY S. CRUMPLER, AND JUSTIN A. SPIELMANN

Assembly Point: Tourist Information Center in Chama

Departure Time: 8 AM

Distance: 47.4 miles

Three stops

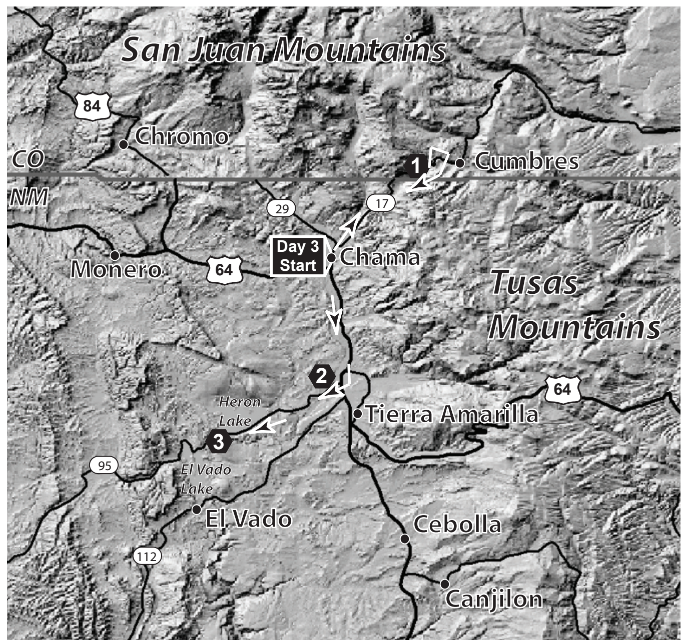
SUMMARY

The third and final day (actually a half day) of this field conference begins with a visit to part of the mid-Cenozoic San Juan volcanic field at the first stop, which is just south of Cumbres Pass near the New Mexico-Colorado state line. The trip then moves south to examine the Pleistocene Brazos lava flow near Tierra Amarilla. It then continues to Heron Lake, to conclude with an examination of Cretaceous depositional systems at the final stop.

0.0 Begin at Information Center in Chama. Turn left on US 64/84 to proceed east. *0.1*

0.1 At stop sign, **turn left** on Highway 17 to proceed north. Note Rabbit Peak at 10:00, composed of Upper Cretaceous Mesaverde Group strata. Chama is built on Pleistocene terrace and alluvial fill of the Rio Chama above bedrock strata of the upper part of the Upper Cretaceous Mancos Shale. Just west and north of town, huge landslide deposits of sedimentary and volcanic rock debris mantle some of the hill slopes (Muehlberger, 1967). These landslides developed on soft, shale-dominated slopes of the Mancos Shale that are particularly susceptible to sliding. The landslide deposits incorporate and/or bury Wisconsin-age (late Pleistocene) glacial deposits, indicating that most of the sliding is relatively recent (Muehlberger, 1967). Indeed, the landslides pose an ongoing maintenance problem for the highway that we will traverse north of Chama. *0.3*

0.4 Upper part of Cretaceous Mancos Shale exposed on east bank of Chama River at 2:00. *0.7*



1.1 Railroad crossing *0.5*

1.6 Historical marker for Chama and Cumbres-Toltec rail road station to right. In 1880-1881, the Denver and Rio Grande Western Railroad laid a narrow-gage line that extended the 500 miles of line that then connected Silverton with Denver. Construction of the 64-mile line from Chama to Antonito, Colorado took more than one year because of steep grades, tight curves, tunnels and the need to build high trestles. The railroad crossed Cumbres Pass (10,023 ft), which is the highest railroad pass in the United States. The narrow gage railroad carried passengers until 1951 and then hauled freight until 1968. In 1971, the railroad reopened as the Cumbres and Toltec Scenic Railroad, which operates a sightseeing train from June to October (Fig. 3.1). *0.2*

1.8 Junction Highway 29 to left, **continue straight.** *0.2*

2.0 At this point, the highway leaves one Wisconsin- (late Pleistocene) age terrace to descend to another younger, Wisconsin-age terrace. *0.3*

2.3 Bridge over Rio Chama. *0.1*

FIGURE 3.1. Locomotive of the Cumbres and Toltec Scenic Railroad.

2.4 Cross railroad tracks. The highway towards Cumbres Pass crosses the Cumbres and Toltec Railroad tracks four times, along which the train climbs a steep 4 percent grade up Wolf Creek to the summit. *0.4*

2.8 Peak at 10:00 is in Brazos Mountains *0.2*

3.0 The panoramic view here was the basis of stop 4 of the first-day road log of the 1960 NMGS Fall Field Conference (Smith and Muehlberger, 1960). Chama Peak at 10:00 is composed of volcanic and volcaniclastic rocks of the mid-Cenozoic Conejos Formation. Here, several hundred feet of Conejos Formation rocks disconformably overlie siliciclastic red beds of the Eocene Blanco Basin Formation. Both of these units are eastward dipping, so there is a pronounced angular unconformity where they overlie westward dipping Mesozoic (Jurassic and Cretaceous) strata. The low gravel ridges rimming the valley here are glacial outwash terraces of the "Durango" (Pleistocene) glacial stage. *0.9*

3.9 Jurassic Morrison Formation in roadcuts to right. Prominent fault in Dakota on left. We are now passing through a gorge cut in Jurassic and Cretaceous strata. *0.4*

4.3 Jurassic Morrison Formation in roadcuts on right for next 0.5 miles. *0.7*

5.0 Highway is now on a glacial moraine. Lower Cretaceous Burro Canyon-Dakota cuesta on left (Fig. 3.2). *1.4*

6.4 Cross Wolf Creek. The gorge now opens into a broad glacial valley, and the highway climbs moraines along Wolf Creek that are dotted with huge boulders. Ahead on left (at about mile 6.8) is turnoff for public access to the upper Rio Chama and type locality of the Eocene Blanco Basin Formation (Fig. 3.3). Gries and Vandersluis (1989, p. 45) write: "The Blanco Basin Formation is composed of terrestrial redbeds deposited in response to the late Laramide (Eocene) episode of mountain-building. The fluviatile red mudstones and gray to yellow, pebbly sandstone found in the formation are similar to the San Jose Formation, a distal equivalent in the San Juan Basin. In the San Juan sag, the Blanco Basin Formation overlies an unconformity developed on strata ranging in age from Precambrian to Paleocene. Current indicators such as pebble imbrications and cross-bedding indicate an easterly source from the Laramide San Luis-Brazos highland. Clast compositions reflect the metamorphic and plutonic core of the source uplift as well as flanking sedimentary Cretaceous and Jurassic strata. The Blanco Basin is generally non-volcanic, although occasional andesitic clasts may be found from reworked Animas Formation." In this area, the Blanco Basin is seen in the reddish cliffs overlying Mancos Shale. *0.2*

6.6 Hereabouts, we cross the Lobato Creek fault, which is primarily a Laramide structure with about 1000 ft of throw down to the east. Muehlberger (1967) indicates that there was also a post-Laramide reversal of this fault, with about 100 ft of throw down to the west. *0.4*

7.0 Highway crosses moraine with enormous erratic boulders of Conejos Formation andesite breccia. *1.0*

8.0 Cross railroad tracks. *0.3*

8.3 Mesa at 3:30 on skyline is Slide Rock Point. It is composed of welded rhyolite tuff of the mid-Cenozoic Treasure Mountain Group. *0.2*

8.5 Note Blanco Basin Formation red beds to left (Fig. 3.4). *0.6*

9.1 Mile marker 9 on right. Blanco Basin Formation red beds unconformably overlie Mancos Shale on left. *0.4*

FIGURE 3.2. Sandstone cuesta of Cretaceous Burro Canyon and Dakota formations at mile 5.0.

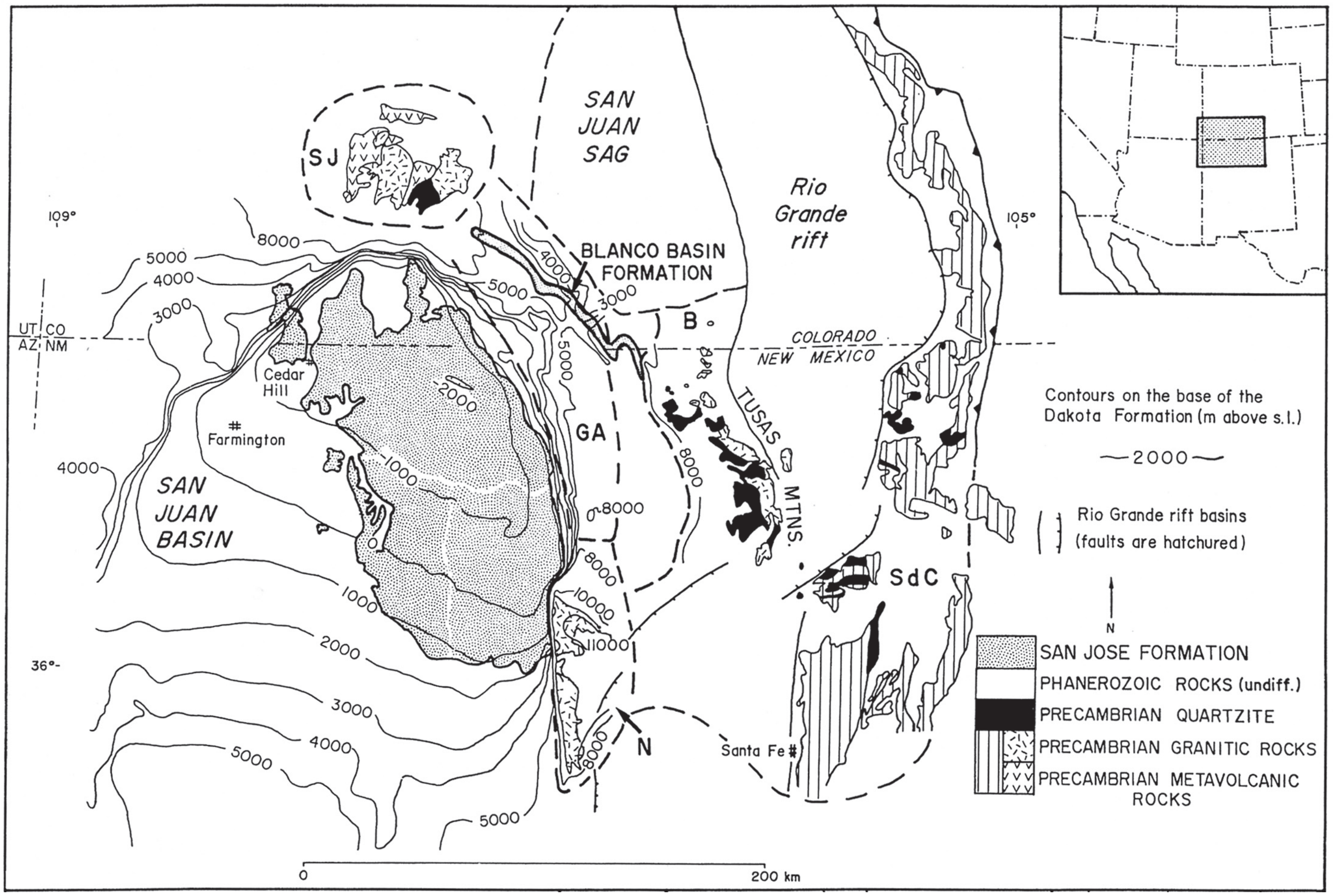


FIGURE 3.3. Location map of the Eocene San Jose Formation, Blanco Basin Formation, San Juan sag and Precambrian outcrops. Uplifts are: B = Brazos, GA = Gallina-Archuleta arch, N = Nacimiento, SdC = Sangre de Cristo and SJ = San Juan (from Smith, 1992).

9.5 Sign says we are leaving New Mexico. *0.3*

9.8 Cumbres Pass Historical Marker on right. *0.2*

10.0 Enter Archuleta County, Colorado. *1.0*

11.0 Enter Conejos County, Colorado. *0.3*

11.3 Note angular unconformity between Jurassic Morrison Formation and Eocene Blanco Basin Formation (Fig. 3.5). Blanco Basin bevels down to Entrada here (Brister, 1992). Gries and Vandersluis (1989, p. 60) write: "View across Wolf Creek canyon. North of this outcrop Mesozoic sediments are not seen on the surface until reaching the north end of the San Juan volcanic field, a distance of about 100 mi. Northeast-dipping Blanco Basin Formation rests on west-south-west dipping Burro Canyon and Morrison. When walking east in the canyon bottom, exposures of progressively older rocks are crossed including possible lower Morrison sandstone or Wanakah sandstone, a thin Todilto Member, and the Entrada Sandstone. The Precambrian is not exposed in the canyon, but it is likely that the Entrada rests directly on Precambrian. Looking across the canyon, the unconformity between the Morrison and the Blanco Basin is angular and to the east Blanco Basin cuts down section and eventually rests on Entrada. To the west, the Blanco Basin rests on Burro Canyon and Dakota. This outcrop

FIGURE 3.4. Red beds of Blanco Basin Formation at mile 8.5.

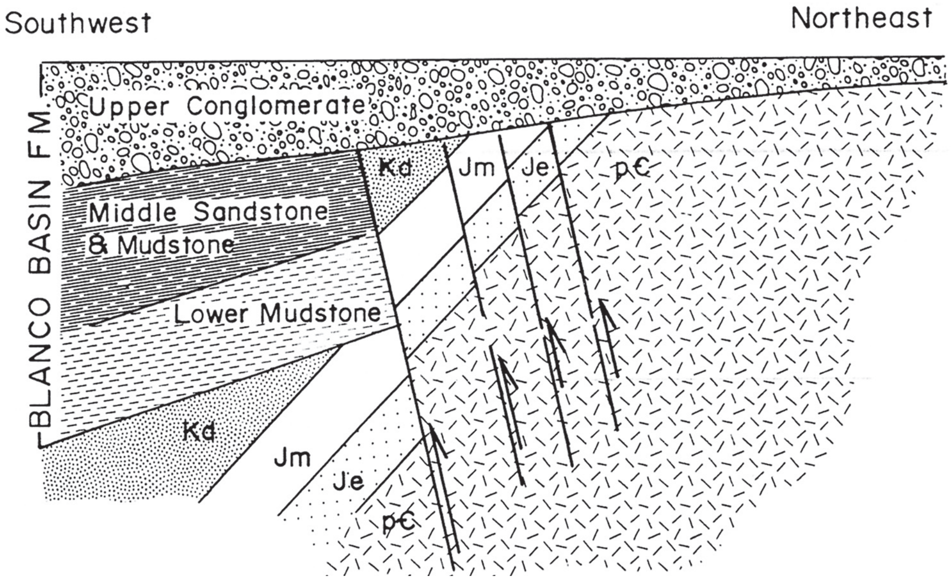


FIGURE 3.5. Schematic cross section interpreting relationships between the Blanco Basin Formation and contemporaneous faults near the depositional basin margin (near Highway 17). Horizontal and vertical dimensions not drawn to scale. Kd = Dakota Sandstone, Jm = Morrison Formation and Je = Entrada sandstone (from Brister, 1992).

is on the west flank of the Laramide Brazos uplift in a zone of reverse faulting. There are at least six reverse faults which are NNE-trending and cut through the Mesozoic strata here. Some slightly offset the Blanco Basin Formation and others apparently do not. This fault zone, proximal to the uplift, is probably responsible for the dramatic thinning of the Blanco Basin in this area as compared to the thicker deposits just a few miles southwest. The Blanco Basin ranges between 9 and 30 ft thick at this location. In general it is a coarse pebble/cobble conglomerate, the clasts of which are very angular, include Mesozoic sandstone and Precambrian rocks, and are crudely imbricated (current direction S60°W). The conglomerates are generally sheet-like, crudely bedded and clast-supported, although pebbly mudstones (clasts supported by mud/silt) can be found which may be the result of mass-flow deposition. On the north side of the canyon, Conejos volcanics overlie the Dakota and Burro Canyon section. There may be a fault between the outcrops on the north and south sides of the canyon." *1.2*

12.5 Cross railroad tracks. Hill at 1:00 is Conejos Formation igneous rocks. *0.7*

13.2 STOP 1: Conejos Formation

Pull off on right

We are now on the southeastern edge of the San Juan volcanic field, which covers an area (mostly in Colorado) of more than 25,000 km^2 and includes a volume of igneous rocks of about 40,000 km^3 (Fig. 3.6). The field consists mostly of intermediate–composition lavas and breccias that erupted during the early Oligocene (about 33-30 Ma) overlain by about 15 widespread and voluminous ash-flow sheets (ignimbrites) that erupted during the late early and late Oligocene (about 30-26 Ma). At about 26 Ma, the volcanism shifted to a bimodal assemblage of mostly trachybasalt and silicic rhyolite that continued into the early Miocene (about 22 Ma) (Lipman, 1975, 1989; Lipman and Mehnert, 1975; Lipman et al., 1996; Smith, 2004).

Here, we will examine an outcrop of the oldest rocks of the field, the Oligocene Conejos Formation (Patton, 1917; Cross and Larsen, 1935, 1956; Muehlberger, 1967; Butler, 1971), which is 33-29.5 Ma, and consists of andesitic and dacitic lava flows and volcaniclastic rocks. This is the volcaniclastic apron of the San Juan volcanic field (Fig. 3.7), which crops out over an area of about 10,000 mi^2 and has an average thickness of 1600 ft, which makes it one of the most extensive volcanic formations of the San Juan field. Indeed, in New Mexico the Conejos Formation extends well to the southeast of our location into the Picuris Range near Taos.

At this stop (Fig. 3.8), the Conejos Formation consists of two facies, a volcaniclastic facies and a vent facies. The volcaniclastic facies conists mostly of reworked material derived from vent facies, including bedded conglomerate sandstone, mudflow breccia containing clasts of dark andesite and rhyodacite. The vent facies is mostly lava flows and flow breccias of aphanitic to porphyritic andesite, rhyodacite, and quartz latite. *3.8*

END OF STOP 1
Retrace route to Chama.

17.0 New Mexico state line welcome sign. *7.2*

24.2 Cross railroad tracks. *0.1*

24.3 Cross Rio Chama. *0.2*

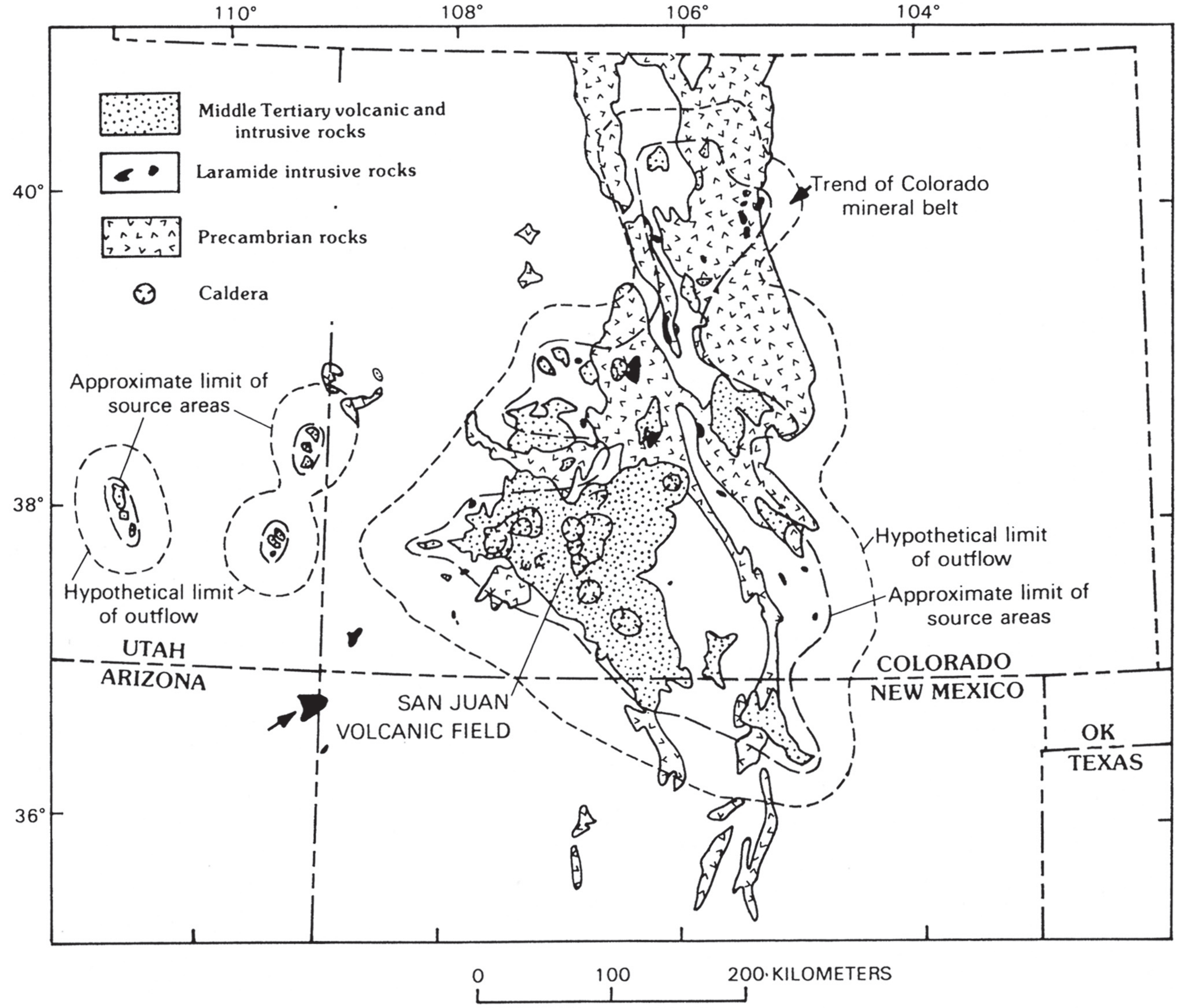


FIGURE 3.6. Map of the southern Rocky Mountains showing location of San Juan volcanic field and nearby mid-Cenozoic igneous centers (from Lipman, 1989).

24.5 Chama village limit. *1.1*

25.6 Cross railroad tracks. *1.0*

26.6 Junction US 84/64. **Go south (straight).** *0.3*

26.9 Cross Rio Chama. *1.4*

28.3 Chama Historical Marker on right, leave Chama. Now we will retrace about 10 miles of the second-day road log. *4.7*

33.0 Roadside table on right. *2.5*

35.5 Junction 512 to left. *0.3*

35.8 Enter Los Brazos. *0.6*

36.4 Leave Los Brazos. *0.1*

36.5 Cross Rio de los Brazos. *0.6*

37.1 **Turn right** on Highway 95. Heron Lake *0.5*

37.6 STOP 2: Brazos Lava Flows

Cross bridge over Rio Chama. Pull off on right.

Roadcuts are in upper part of Upper Cretaceous Mancos Shale. The Brazos cones and flows (Fig. 3.9) are four scoria cones and associated basaltic lava flows of late Pleistocene age; published ages for the Brazos cones are 0.24 ± 0.14 Ma and 0.24 ± 0.06 Ma (Lipman and Mehnert, 1975). These cones and lava flows may be considered extreme western outliers of the general Taos Plateau field volcanism. At least four relatively young cones erupted along the southern crest of the Tusas Mountains. Lava flows from the Brazos cones flowed down the Brazos Box,

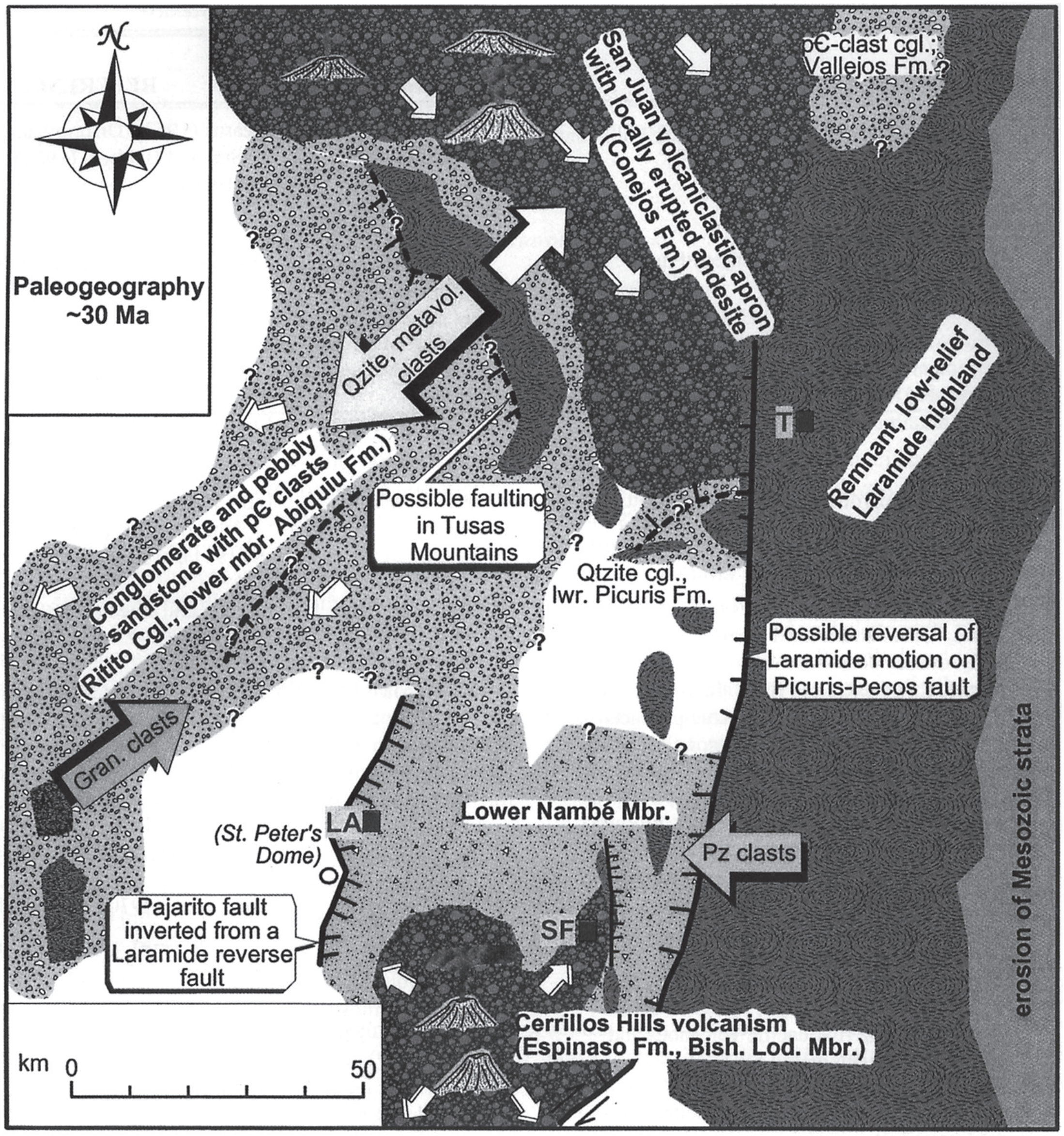


FIGURE 3.7. Paleogeographic map of north-central New Mexico during the Oligocene. LA = Los Alamos, SF = Santa Fe and T = Taos (from Smith, 2004).

decending 2500 ft to the lower elevation floodplains at Tierra Amarilla where Highways 84 and 95 cut through the flow. This drop in elevation represents about a tenth of one Earth atmospheric scale height, implying that the vesicularity of the lava flows erupted from the Brazos cones and exposed in the road cuts here and nearby along Highway 84 may be significantly different from the vesicularity of lavas erupted at elevations similar to Tiierra Amarilla (7400 feet). Because the inherited vesicularity at the vents should be the same as the vesicularity of the distal flows, any difference must relate to the change in elevation.

We will now drive down section through much of the Mancos Shale, beginning with the El Vado Member and descending through the middle shale, Juana Lopez, Carlile, Greenhorn and Graneros members as we leave this stop (Landis and Dane, 1967). *1.6*

END OF STOP 2

Continue west on Highway 95.

39.2 Cross cuesta developed in the El Vado Member of the Mancos Shale. *0.4*

39.6 Crest of ridge developed in the El Vado Member of Mancos. *1.1*

40.7 Crest of hill. Upper Cretaceous Carlile Member of Mancos Shale. There is a distinct unconformity in this region within the Late Cretaceous section that separates the

FIGURE 3.8. Outcrop of Conejos Formation at Stop 1.

"Carlile interval" (strata of Turonian age) from the overlying "Niobrara interval" (strata of Coniacian age) (see accompanying minipaper). *0.2*

40.9 Paved road to left (Junction 572), **continue straight.** *1.0*

41.9 Cross ridge in Carlile and Juana Lopez members of Mancos Shale. *0.5*

42.4 Greenhorn Member roadcuts on both sides of the road. *0.1*

42.5 Enter Heron Lake State Park. Greenhorn Member in roadcuts on left (limestone and calcareous shale beds). *0.3*

42.8 Good Greenhorn Member outcrops on left. *0.5*

43.3 Carlile to Juana Lopez members on right. Outcrop of Juana Lopez Member here yields numerous specimens of the characteristic Turonian oyster *Lopha lugubris* (Fig. 3.11). *0.2*

43.5 Heron Lake Visitor Center on right. Continue straight. Heron Lake beyond. "The San Juan-Chama Project diverts flow from three streams in the San Juan River headwaters, carries the water in tunnels bored through the mountains, and discharges the flow into Willow Creek, a tributary of the Rio Chama. Willow Creek flows into Heron Reservoir, a 400,000 af (acre feet) facility constructed to store project waters only; no water natural to the Rio Chama can be legally stored at Heron. Water released from Heron flows through El Vado, Abiquiu lakes prior to joining the Rio Grande upsteam of Española. The San Juan-Chama Project provides a firm yield of 94,000 af to Rio Grande users for irrigation, domestic, industrial, recreational, fish, and wildlife purposes. The Project, constructed by the Bureau of Reclamation, first delivered water to the Rio Grande basin in 1970." See Shupe and Folk-Williams (1988) and the accompanying minipaper. *0.4*

Roadlog continues on page 66

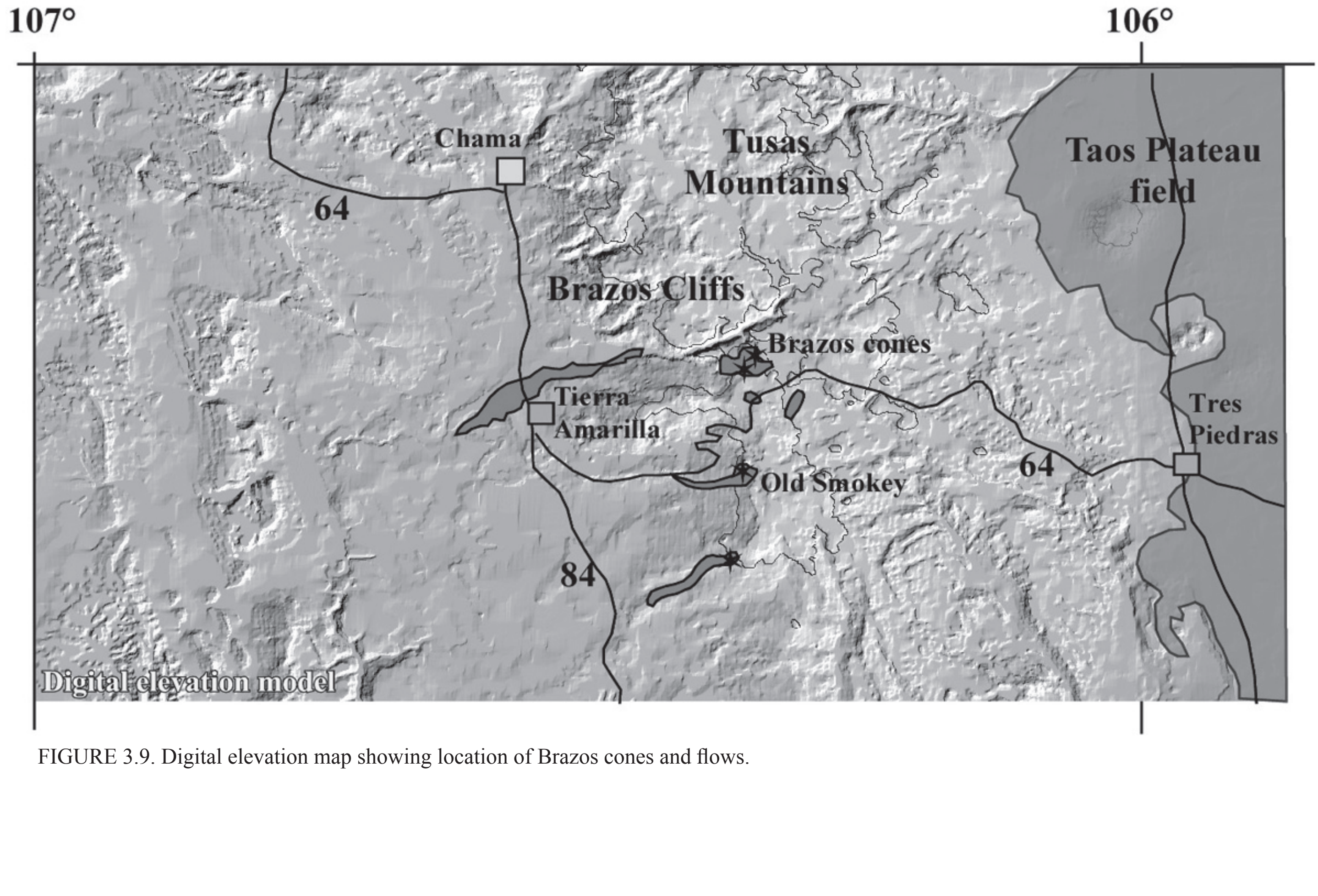


FIGURE 3.9. Digital elevation map showing location of Brazos cones and flows.

COOPER ARROYO SANDSTONE MEMBER OF THE MANCOS SHALE (CRETACEOUS) OF THE CHAMA BASIN, NEW MEXICO

Spencer G. Lucas
New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM 87104

One of the classic stratigraphic relationships in the Upper Cretaceous sedimentary rocks of northwestern New Mexico is the presence of a regional unconformity between rocks of Carlile (Turonian) and Niobrara (Coniacian) age. In the San Juan Basin, the oil-bearing Tocito Sandstone represents inner shelf sand ridges that were deposited on this unconformity (Lamb, 1968; McCubbin, 1969; Molenaar, 1973, 1983; Nummedal et al., 1993). In the Chama Basin, the Cooper Arroyo Sandstone Member of the Mancos Shale (Fig. 3.10) rests on this unconformity (Landis and Dane, 1967; King, 1974).

Landis and Dane (1974, p. 7-8) named the Cooper Arroyo Sandstone Member for a thin (up to 1 m thick), coarse-grained (and locally pebbly), glauconitic sandstone interval that is typically ripple laminated or crossbedded (Fig. 3.10). It was named for Cooper Arroyo, south of El Vado Reservoir, and the type section is in the N1/2 Sec. 20, T27N, R2E, Rio Arriba County. Landis and Dane (1967) mapped the distribution of the Cooper Arroyo Sandstone Member on the Tierra Amarilla 15-minute quadrangle map. It has a sharp and irregular basal contact on silty shale of the unit they informally termed the lower part of the "Middle Shale Unit" of the Mancos Shale. This unit yields late Turonian fossils (such as a *Scaphites* very similar to *S. ferronensis*: King, 1974) and is equivalent to the D-Cross Member of the Mancos Shale to the south.

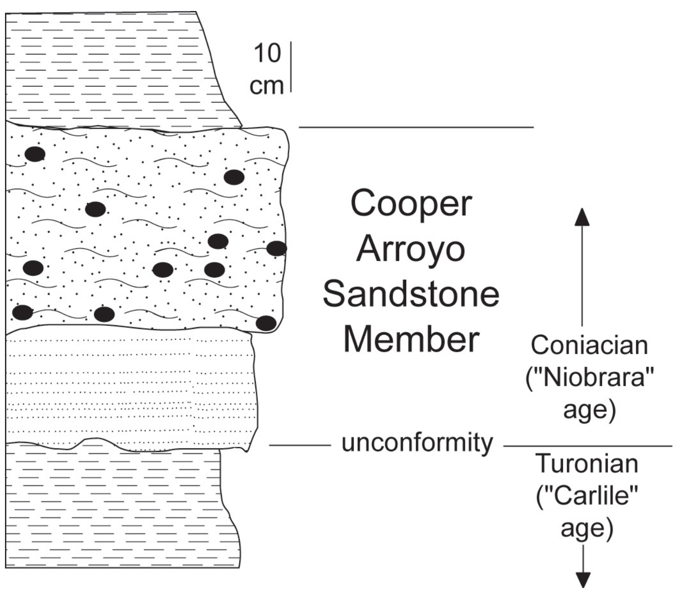


FIGURE 3.10. Type section of the Cooper Arroyo Sandstone Member (based on data in Landis and Dane, 1967).

Fossils from the Cooper Arroyo Sandstone Member include shark teeth, the ammonite *Placenticeras* sp. and the bivalves *Ostrea congesta* and *Inoceramus* cf. *I. inconstans woodi* (originally identified as *I. erectus*, but see King, 1974). These fossils indicate a Coniacian, but not an earliest Coniacian age (Landis and Dane, 1967; King, 1974; Landis et al., 1974). Thus, time is missing between the Cooper Arroyo Sandstone Member and underlying strata. This biostratigraphic evidence of a hiatus combined with the sharp lithologic break at the base of the Cooper Arroyo Sandstone Member and the erosional relief at its base (tens of meters of section are locally missing beneath it, if the Juana Lopez Member below is used as a datum) are strong evidence it is sitting on the Carlile-Niobrara unconformity.

Strata above the Cooper Arroyo Sandstone Member are calcareous and silty shales with an inoceramid fauna that indicates it is equivalent to the lower interval of the Smoky Hill Member of the Niobrara Formation (King, 1974). Thus, the Cooper Arroyo Sandstone Member is a thin, coarse-grained to pebbly, glauconitic sandstone unit that rests on the Carlile-Niobrara unconformity in the Chama Basin. It is lithologically similar to and in the same stratigraphic position as the Tocito Sandstone in the San Juan Basin. Therefore, the name Cooper Arroyo Sandstone Member is an unnecessary synonym of Tocito Sandstone. In the Chama Basin, the name Cooper Arroyo Sandstone Member thus should be abandoned and replaced with Tocito Sandstone.

REFERENCES

King, N. R., 1974, The Carlile-Niobrara contact and lower Niobrara strata near El Vado, New Mexico: New Mexico Geological Society, 25th Field Conferenced Guidebook, p. 259-266.

Lamb, G. M., 1968, Stratigraphy of the lower Mancos Shale in the San Juan Basin: Geological Society of America Bulletin, v. 79, p. 827-854.

Landis, E. R., and Dane, C. H., 1967, Geologic map of Tierra Amarilla quadrangle, Rio Arriba County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 19, scale 1:62,500.

Landis, E. R., Dane, C. H. and Cobban, W. A., 1974, Cretaceous rocks of the Tierra Amarilla coal field and adjacent areas, Rio Arriba County, New Mexico: New Mexico Geological Society, 25th Field Conference Guidebook, p. 231-238.

McCubbin, D. G., 1969, Cretaceous strike-valley sandstone reservoirs northwestern New Mexico: American Association of Petroleum Geologists Bulletin, v. 53, p. 2114-2140.

Molenaar, C. M., 1973, Sedimentary facies and correlation of the Gallup Sandstone and associated formations, northwestern New Mexico: Four Corners Geological Society Memoir, p. 85-110.

Molenaar, C. M., 1983, Major depositional cycles and regional correlations of Upper Cretaceous rocks, southern Colorado Plateau and adjacent areas; in Reynolds, M. W. and Dolly, E. D., eds., Meszozoic paleogeography of the west-central United States: Denver, RMS-SEPM, p. 201-224.
Nummedal, D., Wolter, N. R., Fleming, T. F., Bergsohn, I. and Swift, D. J. P., 1993, Lowstand, shallow marine sandstones in Upper Cretaceous strata of the San Juan Basin, New Mexico; Geological Association of Canada, Special Paper 39, 199-218.

THE SAN JUAN-CHAMA PROJECT

Kristan Cockerill
Cockerill Consulting, P.O. Box 7731, Albuquerque, NM 87194, kristanc10@earthlink.net

The legal and political details of western water management are incredibly convoluted and rarely in perfect sync with the geologic and hydrologic realities. The San Juan-Chama Project is no exception. Via this $78 million Bureau of Reclamation effort, Colorado River Basin water travels under the Continental Divide, through almost 38 miles of concrete tunnels and conveyance channels to reach Heron Reservoir in the Rio Grande Basin. Congress approved this Project in 1962, amending the Colorado River Storage Act of 1956 as the means to provide New Mexico with its legal entitlement to Colorado River water. The idea for the project, however, dates back to 1933 when the Bunger Survey established that it was feasible to bring San Juan River water into the Rio Grande Basin.

Heron Dam is one of five dams, three tunnels and other facilities constructed in the 1960s and 70s to move water across the basins. Water diversion begins on the Rio Blanco, Navajo and Little Navajo rivers, all of which are tributaries to the San Juan River in southern Colorado. Through the Project facilities water is transported into the Chama River in the Rio Grande Basin and into Heron Reservoir (Table 3.1). Water is then released through El Vado Reservoir and Abiquiu Reservoir and finally reaches the Rio Grande. Although El Vado and Abiquiu reservoirs contain San Juan-Chama Project water, they were not constructed as part of the Project. El Vado was built in 1935 to provide irrigation water to Middle Rio Grande farmers, and Abiquiu is a Corps of Engineers effort.

There are minimum bypass requirements to maintain flows in the Rio Blanco, Navajo and Little Navajo rivers, so the flow into Heron Reservoir is determined by the streamflow in southern Colorado. The Bureau of Reclamation allows contracts for 96,200 acre-feet of water from the Project. The majority of the water is contracted to the City of Albuquerque (48,200 acre-feet) and the Middle Rio Grande Conservancy District (20,900 acre feet). Other significant contractors include the Jicarilla-Apache Tribe (6,500 acre-feet), the City of Santa Fe (5,605 acre feet) and Cochiti Reservoir Recreation Pool (5,000 acre-feet). Interestingly, when the Project was first approved, there was little demand for the water, and water rights remained available for contract into the 21st Century. Those municipalities and other organizations who contract for the water are repaying the Bureau's construction bill.

The Middle Rio Grande Conservancy District supports irrigation on more than 50,000 acres and has contracted San Juan-Chama Project water since 1963. Although it purchased rights to the water in 1963, Albuquerque will not begin fully using its allotment until 2006 when it finishes new drinking water facilities to treat and transport San Juan-Chama Project water. Once local facilities are completed, Albuquerque will draw the majority of its water from the San Juan-Chama Project instead of the Santa Fe Group aquifer, except in times of drought and subsequent low flow conditions. For years, Albuquerque has leased its San Juan-Chama Project water rights to others, including to the Conservancy District to support irrigation and to the Bureau of Reclamation to support instream flow for endangered species. As Albuquerque and others begin fully using their water rights, this will affect flows throughout the system.

Perhaps the most interesting issue surrounding the Project is recognizing the distinction between "wet" water and "paper" water. While various entities along the Rio Grande certainly own rights to the San Juan-Chama Project water, in drought years those "paper" rights do not produce more "wet" water to be distributed. In fact, the Middle Rio Grande Regional Water Plan stated that, "It is understood that even though the plan assumes the full San Juan/Chama Project allotment, there is a possibility that it will not be received every year." In early January 2005, Heron Reservoir held about 111,000 acre-feet, well below its 400,000 acre-feet capacity. If drought conditions continue, the availability of "wet" water will become even more salient. Other complicating factors include the hierarchy of water rights. Six pueblos have storage rights at El Vado, and these rights are considered prior and paramount, or the most senior rights. The Rio Chama Acequia Association has senior rights on the Rio Chama, and reservoir operations may not impede these rights. Additionally, the Rio Chama between El Vado and Abiquiu is a federally designated Wild and Scenic River. To date, the timing of San Juan-Chama Project water releases has been used to insure instream flow.

Concern about water levels in the Rio Grande has prompted significant debate and litigation over the San Juan-Chama Project. Much of the debate has centered on compliance with the Endangered Species Act, specifically related to using Project water to support the Rio Grande silvery minnow (*Hybognathus amarus*). This tiny fish lives only in the 157-mile reach from Cochiti Dam in Sandoval County south to Socorro County. In recent years litigation about silvery minnow habitat requirements and San Juan-Chama Project water prompted Albuquerque mayor Martin Chavez to declare that providing water for the fish would mean taking water from Albuquerque children. This particular debate was rendered moot in November 2004 when the federal fiscal year 2005 Energy and Water Development Appropriations Bill prohibited the Secretary of Interior from requiring San Juan-Chama Project water to be used to meet Endangered Species Act requirements. That appropriation also included more than $6 million dedicated to minnow recovery.

Despite this federal decision, the controversy continues. A key concern is that there remains significant uncertainty in our understanding of the relationship between groundwater pumping and river flows. Hence, Albuquerque's plans to shift to surface water use may have unintended and unforeseen consequences, and there is debate as to whether this eventuality is adequately addressed in the implementation strategy for the new drinking water facilities. Therefore, a coalition of agricultural and conservation groups challenged Albuquerque's drinking water project permit application to the State Engineer in 2003. There was an administrative hearing that resulted in adding conditions to the city's permit. There were, however, several unresolved issues, and in the summer of 2004 the groups appealed the permit that State Engineer John D'Antonio had approved. Expect controversy surrounding the San Juan-Chama Projects "wet" and "paper" water to continue for the foreseeable futture.

TABLE 3.1. San Juan-Chama Project Water Transport System

Facility	Capacity	Length	Route
Blanco Tunnel	520 cfs	8.6 mi	Rio Blanco to Little Navajo River
Oso Tunnel	650 cfs	5.1 mi	Little Navajo River to Navajo River
Azotea Tunnel	950 cfs	12.9 mi	Navajo River to Azotea Creek
Conveyance channels		11 mi	Azotea Creek to Willow Creek to Heron Reservoir

REFERENCES

Apodaca, Ted. 2000. *The Rio Grande Silvery Minnow in Court*. Waterlines. <http://www.seo.state.nm.us/publications/waterlines/wl-winter-2000/ss4.html>, accessed 16 January 2005.
City of Albuquerque Water Utility Department., 2005, <http://www.cabq.gov/waterresources/sjc.html>, accessed 16 January 2005.
Gould, Jaci, 1999, *San Juan/Chama Project Water Use*. The Rio Grande Compact: It's the Law!. Water Resources Research Institute Conference Proceedings.
Harris, Steve (Rio Grande Restoration). 2005. Personal commun.
Middle Rio Grande Water Assembly and the Mid Region Council of Governments. 2003. Middle Rio Grande Regional Water Plan, 2000-2050.
Office of Senator Pete V. Domenici. 2004. Domenici Announces $6.15 Million for Middle Rio Grande Minnow Recovery in '05. Press release, 23 November.
Soussan, Tania. 2003. *San Juan-Chama Transfers Water from 3 Rivers to N.M*. Albuquerque Journal, June 1.
US Bureau of Reclamation, San Juan-Chama Project Colorado and New Mexico. <http://www.usbr.gov/dataweb/html/sjuanchama.html> accessed 16 January 2005.
US Bureau of Reclamation, San Juan-Chama Project Fact Sheet. <http://www.usbr.gov/uc/albuq/envprog/mrg/fact/sjc_proj.pdf>.

43.9 Willow Creek Recreational Area on right. Continue straight. *0.3*

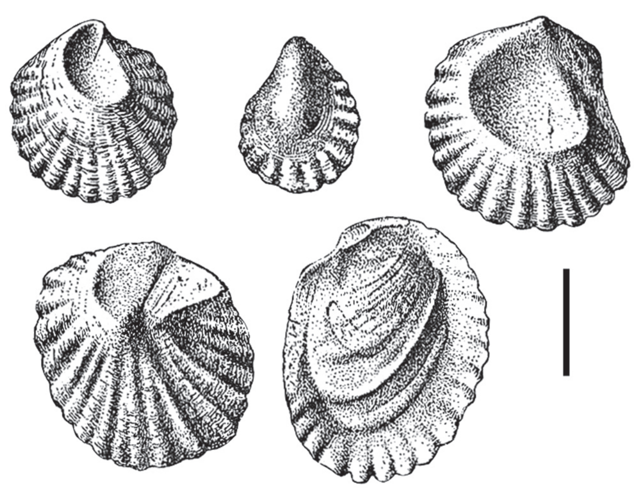


FIGURE 3.11. The oyster *Lopha lugubris*, an excellent Turonian guide fossil characteristic of the Juana Lopez Member of the Mancos Shale; Scale bar = 1 cm (modified from Stanton, 1893).

44.2 Greenhorn Member in roadcuts for next 0.6 miles. *0.8*

45.0 Graneros/Greenhorn contact in roadcut on left, continues next 0.6 miles. *0.2*

45.2 Good view of Heron Lake to right. *2.0*

47.2 **Turn left** on Rio Chama Trailhead Road. *0.1*

47.3 Road forks, **stay left**. *0.1*

47.4 STOP 3 – Burro Canyon-Dakota Contact

Walk down road to right to base of dam.

This stop is at the steep roadcut made during construction of Heron Dam, which dams Willow Creek at its confluence with the Rio Chama. At the base of the stratigraphic section here is a thick section of Burro Canyon Formation (Figs. 3.12-3.13). The Burro Canyon contains more green mudstone here than at the HW84 section (Day 2, Stop 4).

The K-1 unconformity is poorly exposed at the base of the Burro Canyon where it overlies Morrison Brushy Basin Member

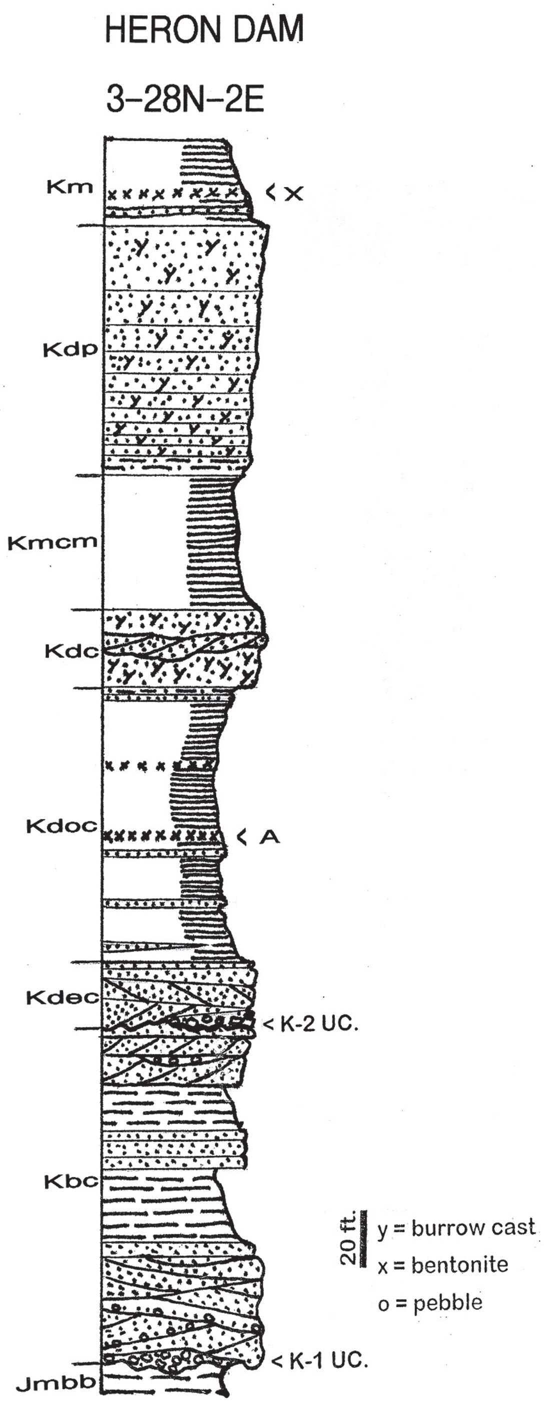


FIGURE 3.12. Measured stratigraphic section of Burro Canyon Formation and Dakota Sandstone at Heron Dam roadcut. Jmbb = Morrison Fm., Brushy Basin Member; Kbc = Burro Canyon Fm.; Kdec = Dakota Ss., Encinal Canyon Member; Kdoc = Dakota Ss., Oak Canyon Member; Kdc = Dakota Ss., Cubero Ss. Tongue; Kmcm = Mancos Sh., Clay Mesa Shale Tongue; Kdp = Dakota Ss., Paguate Ss. Tongue; Km = Mancos Sh. Note presence of Mancos Sh., Clay Mesa Sh. Tongue, which was absent at the HW84 measured section. The Cubero is much thinner here because the upper parasequence is channeled into the lower parasequence. The Paguate is much thicker here and northward into Colorado. Both the A bentonite in the Oak Canyon and the X bentonite in the shale above the Paguate are present here. These two bentonites are the best log markers in the San Juan Basin to the west.

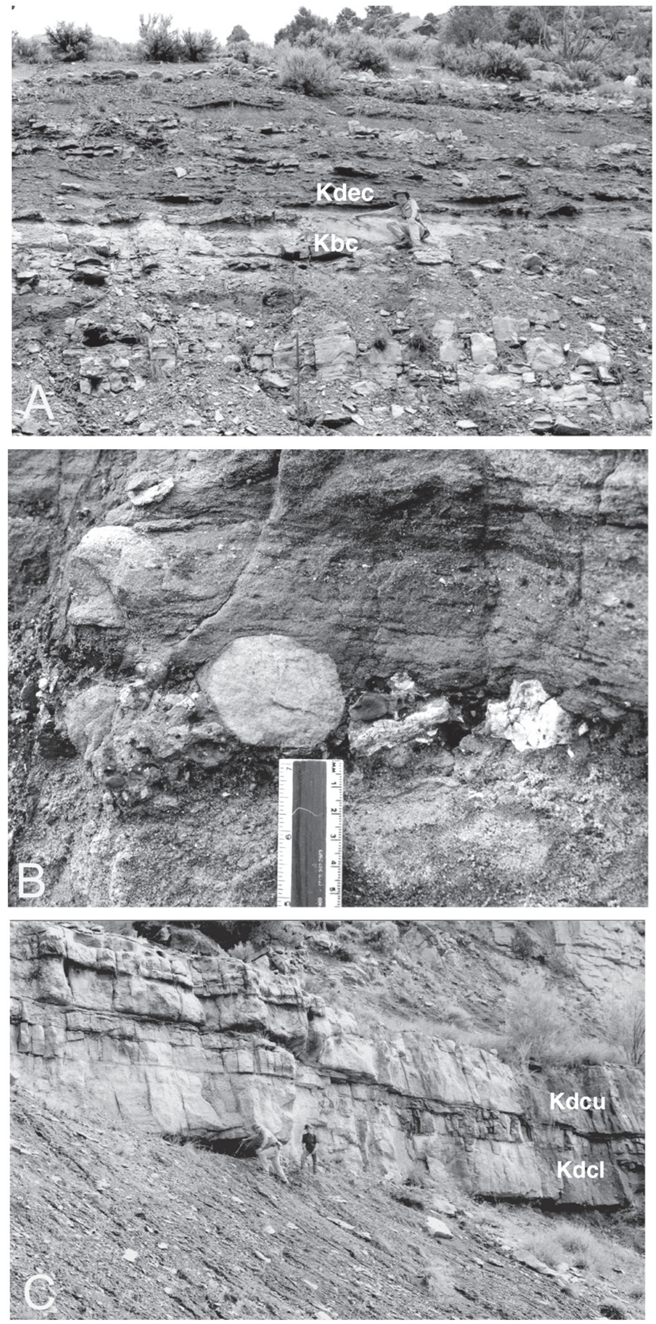


FIGURE 3.13. Selected outcrops at Heron Dam roadcut. A, Burro Canyon-Dakota contact at K-2 unconformity, Heron Dam stratigraphic section. Person's hand is at K-2 unconformity. Kbc = Burro Canyon Formation; Kdec = Dakota Ss., Encinal Canyon Member. B, Close-up photograph of basal lag conglomerate on K-2 unconformity in Dakota Sandstone, Encinal Canyon Member, on Burro Canyon Formation at Heron Dam stratigraphic section. Top of ruler at unconformity. C, Cubero Sandstone Tongue of Dakota Ss. at Heron Dam stratigraphic section. Kdcl = lower Cubero parasequence; Kdcu = upper Cubero parasequence. Note that upper parasequence is channeled into lower parasequence.

mudstones downstream at river level. The K-2 unconformity may be seen as a shallowly channeled surface at the top of the Burro Canyon overlain by a thin Dakota Encinal Canyon Member sandstone. The top of the Encinal Canyon is marked by a prominent marine-flooding surface with a fine-grained lag gravel. The Dakota Oak Canyon Member is similar to the HW84 section, including the A bentonite bed, although it is not as well exposed.

The thickness of the upper Dakota units at Heron Dam are distinctly different from HW84. The Cubero Sandstone Member of the Dakota is only 25 ft thick here because the crossbedded upper parasequence channels into the bioturbated lower parasequence. Approximately 40 ft of the Clay Mesa Shale Tongue of the Mancos is present here between the Cubero and Paguate sandstones; this unit gradually wedges out southward and is absent at the HW84 section. The Paguate Sandstone Member of the Dakota, which forms the rimrock of the Chama Canyon here, greatly thickens northward from the HW84 section to here, where it is a 70-ft thick, classic, fining-upward, bioturbated parasequence. This thickening continues northward into Colorado reaching nearly 100 ft north of Pagosa Springs. The X bentonite, a widespread marker in much of the Western Interior seaway is 9 ft above the marine-flooding surface at the top of the Paguate here at the Heron Dam section. The Greenhorn Limestone Member of the Mancos Shale occurs along the paved highway near the top of the dam.

This is the last formal stop of the field conference, but those who wish may follow the supplementary road log south of here to the west end of El Vado Dam to examine an excellent exposure of upper Dakota, Graneros Shale, and Greenhorn Limestone.

END OF DAY 3 LOG